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Deep Learning Approaches for Information - Centric Network and Internet of Things

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ABSTRACT

Technologies are rapidly increasing with additions to them every single day. Cloud Computing and the Internet of Things (IoT) have become two very closely associated with future internet technologies. One provides a platform to the other for success, the benefits of which could be from computing to processing and analyzing the information to reduce latency for real-time applications. However, there are a few IoT devices that do not support on-device processing. An alternate solution of this is Edge Computing, where the consumers can witness a close call with the computation and services. In this work, we will be to studying and discussing the application of combining Deep Learning with IoT and Information-Centric Networking. A Convolutional Neural Network (CNN) model, a Deep Learning model, can make the most reliable data available from the complex IoT environment. Additionally, some Deep Learning models such as Recurrent Neural Network (RNN) and Reinforcement Learning have also integrated with IoT, which can also collect the information from real-time applications.

KEYWORDS: *Deep Learning, Internet of Things, Edge Computing, Information-Centric Networking*

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I. INTRODUCTION

The current Network Infrastructure Model for the Internet is witnessing an ultimate increase in connected devices, applications, and a massive exchange of information. This model can handle a considerable number of devices and services but not for much longer. Here arises the need for a new model for the future of the Internet. Information-Centric Network is a new, capable, and adaptable approach that can be a better replacement for the current host-centric paradigm. In this approach, the connectivity may not be continuous as the use of IP addresses is eradicated. Instead, the network functionalities are based on the content requested by the end-user or required by the devices.

Moreover, data becomes independent from location restrictions, applications, and ways of importing or exporting it, enabling caching and duplication in the network. This technique may result in improving overall efficiency. Better scalability is seen in the bandwidth demand. This paradigm's security mechanisms are directly applied to the content itself rather than securing the communication channel.

In addition to this, Edge Computing has become a significant technology in today's world of Internet that goals to replace Cloud-based technologies. Compared to the cloud-based world where the processing and computing processes centralize from the network perspective, in any case, it may not be as fast as it is required to process IoT applications. Edge/Mobile Computing offers a decentralized architecture for computing, storage, and connectivity, which can accelerate real-time applications.

Meanwhile, the Internet of Things (IoT) faces plenty of challenges, from connectivity, due to the availability of a vast number of diverse devices and services to much other middleware software and hardware required for the execution. There is a noticeable shift of internet users and application requirements from a host-oriented approach to a data-oriented one. The main focus is the consumer content rather than the host producer.

The previously mentioned issues could get resolved by establishing ICN on top of IoT. ICN is an appropriate architecture for IoT. Using the content name, the diverse issues amongst the vendors and the need for middleware diminishes. Moreover, ICN enhances the content availability by caching it in the network and further replicating it and avoids continuous communication with the maker. Additionally, bringing the computation much closer to consumers enhances real-time communication, reliability, and security. Edge Computing improves the IoT arrangement. The rigid design perspective restricts the structure of the current traditional network. It becomes tough to meet the increasing number of user's demands and the massive number of connected devices. However, ICN is capable of overcoming these challenges. A ubiquitous caching scheme is essential for IoT in the Edge Computing approach between the sophisticated and advanced ICN principles.

This work discusses some research techniques proposed based on Machine Learning (ML) approaches, including Support Vector Machine (SVM), that directs to search for a separated hyper plane by maximizing the boundary between all training data and Support Vector Regression. Linear establishes a relation between the dependent and one or more Independent variables. It tends to predict an output based on some scalar variables.

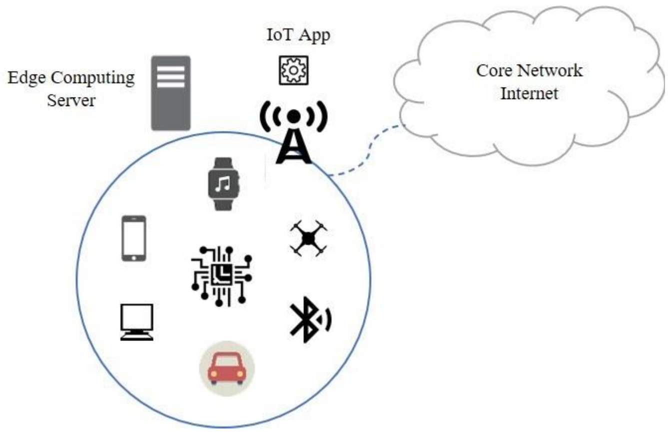

Fig. 1. Edge Services

Moreover, Deep Learning (DL) shows extraordinary computer science performance, including Natural Language Processing, Bioinformatics, and Computer Vision. AI is a broad discipline of developing intelligent systems wherein DL is a fundamental concept in AI that refers to a system that learns from tremendous data experiences. DL has the potential to perform a robust analysis over a vast volume of data. It has a set of learning approaches, which seek to model a problem based on high-level data. There are various research attempts proposed in this literature, all related to IoT and EC.

Therefore, DL is considered the most promising approach for data processing and analysis in IoT. In most cases, IoT data is device-driven and does not require human interference for receiving and processing the data. In the wake of recent trends in real-time applications, a possible need to minimize the response time of services and enhance service quality and experience arises. Such requirements are usually tough to fulfill, especially with many devices, vast amounts of data, and challenging deployment. We shall also introduce a significant component that makes the Edge more intelligent and enhances the IoT.

II. CHANCES OF BRINGING ICN-IOT TO THE EDGE

From the perspective of the host-centric paradigm, most of the services are deployed on the core network. It means that all the requests would be fulfilled from the network to the Edge, wherein a massive number of resource-constrained IoT devices are already deployed. Thus, heavy uplink traffic would be required. Also, the possibility to request the same content many times can occur. Therefore, bringing those services closer to the IoT devices will improve network performance and make it more distributed. Further, due to in-network caching, ICN will add a more distributed nature to the network.

Due to the miscellaneous numbers of IoT applications, a massive amount of miscellaneous content is produced. Hence, the actuators may require all available data to counter different changes. However, communicating all the Edge data is not feasible, especially when the connectivity is low and limited bandwidths, energy, and processing space. Fig. 1 demonstrates a simple IoT service running at the Edge. IoT devices may send the data that the Edge Computing Server needs to be processed via IoT Gateway Application and later can be communicated over the Internet or Cloud Services if there are even more processing tasks. Hence, an effective and efficient management arrangement is required at the Edge to consider the data needed for processing carefully and, at the same time, must be forwarded to the Internet or Cloud.

Establishing such computation arrangements at the Edge along with a ubiquitous in-network caching, would inevitably radically optimize the network performance. Installing DL services at the Edge enables fast processing of data and enhances business control and management.

On the contrary, by enabling in-network caching, the storage problem on IoT devices can prevail. A collaborative ICN in-network caching can enhance the entire IoT network's data distribution and satisfy the demands at any node Irrespective of the content maker. Usually, the introduction of DL in ICN-IoT helps to decrease a large number of various IoT devices and services and facilitates vast data processing and analysis.

III. DL ON THE TOP OF ALL AT THE EDGE

These various devices and applications generate many data and involve real-time communication. Thus, the objective here is to use such models to facilitate efficient results compared to other classical approaches. We use DL to its fullest on the top of EC to maximize IoT applications' advantage to enhance the user experience and network traffic and improve the learning performance. Usually, such models store the content in real-time, reduce computation time, and optimize complex EC operations. The DL uses a Deep Neural Network (DNN) consisting of various layers. Each of these layers consists of several other neurons.

A. Convolutional Neural Network for ICN-IoT at the Edge

In an IoT eco-system (Fig. 2), multiple devices are deployed at the Edge, generating a large amount of data on the link flow traffic high traffic congestion on the network. Therefore, the Convolutional Neural Network (CNN) can integrate all components of ICN-IoT and EC. CNN architecture is based on the following four fundamental concepts:

- **Pooling:** reduces the dimensions of the data and therefore is a form of sub sampling of the input data. The input data is sliced into an array of frames of n non-overlapping side points. Each frame can be seen as a tile. The output of each tile is estimated according to the values taken by the different points of the tile.
- **Receptive field:** it typically represents a sub-area giving rise to stimuli to which the neuron updates its behavior.
- **Weights:** are referred to as value in the matrices or multiplicative factor of the filters. Elements may get updated by the shared weights multiple times during the training with a back-propagation algorithm.
- **Activation:** is a mathematical function that transforms the input signal into some unit and then into an output signal.

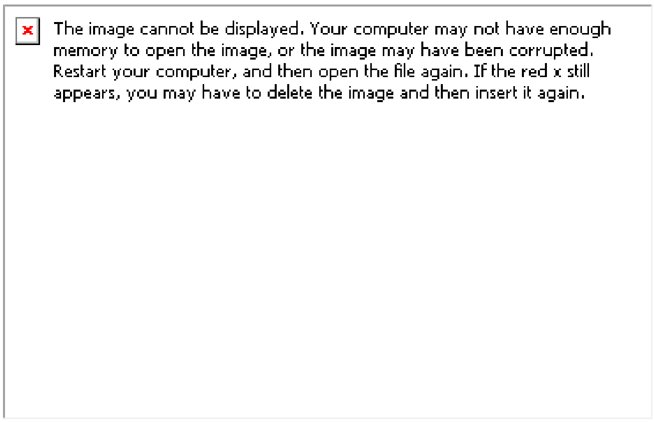

Fig. 2. Basic Concept of CNN

One of the main advantages of this model is to utilize the data from a complex IoT environment, e.g., implementing image detection using CNN in the IoT devices, streaming hardware accelerator to enhance the energy efficiency.

Considering the quality of the transferred data from IoT applications, a Graph Convolution Network (GCN) is developed to integrate the graph topology and local vertex features in the convolutional layers. This model's advantage is breaking down the multi-modal data into several sub graphs in the convolutional neural layers to keep the relations intact.

B. Recurrent Neural Network Real-Time IoT

In today's world, Real-time data analytics has gained significant importance in the field of IoT. Recently, a few DL models such as Recurrent Neural Network (RNN) and Long-Short Term Memory has been anticipated by many for real-time data processing.

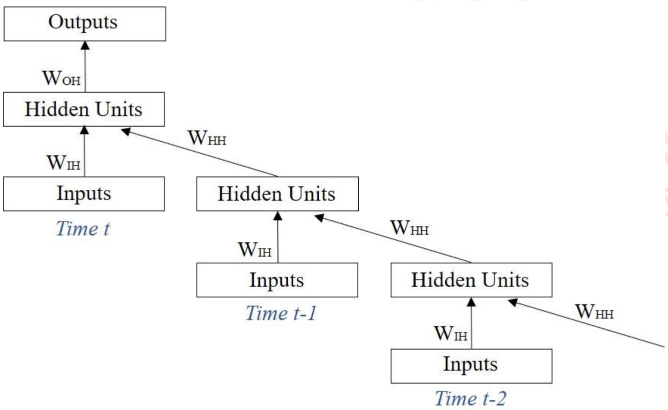

Fig. 3. Basic Concept of RNN

The main advantage of using such models is storing the data exchange history and providing a platform for online processing. The exchanged information can traverse in both directions. In Traditional deep networks, the input and output sizes are fixed and cannot be updated. Moreover, they tend not to share the features learned across various positions in communication. RNN diminishes these constraints by allowing the storage of historical events and facilitate in predicting future events using flexible sizes for inputs and outputs.

We observe that RNN and CNN are suitable solutions to overcome the issues of using ICN-IoT at EC. RNN also uses a back-propagation algorithm through time, which is applied for every timestamp. We can also notice that these models are fundamental in IoT applications, which can be useful in several domains, i.e., collecting/sensing eco-system data in military and civilian settings. One of the advantages is to reduce the computing and processing tasks of miscellaneous data in real-time applications. For this very reason, we anticipate to use a CNN model to align ICN-IoT with EC, and RNN to take into account the temporal aspects.

C. Reinforcement Learning

Recently, reinforcement learning (RL) has been proposed in IoT applications, focusing on large-scale wireless communication and bringing in a two-layer framework to estimate the handover controllers (HO). This framework supports both the regular cellular devices and IoT devices in various user mobility patterns. A collaborative RL approach is adapted to allow each device to learn the HO and DNN. A supervised learning method is also introduced to adjust and initialize the DNN before executing the RL process. Some researchers and scientists also aim to apply a semi-supervised deep reinforcement learning model for IoT Smart City. The proposed model utilizes both labeled and unlabeled data to improve the learning agent's accuracy and performance.

Although there were significant developments in network models, GPU memory, and training techniques, the fact that training the network model can impractically take more extended time on a single machine remains the same. Therefore, we shall not be limited to a single machine. A prominent amount of work and research has been conducted recently to facilitate distributed neural networks training efficiently.

IV. FUTURE WORKS

TCP/IP model has dominated the whole world of Internet infrastructure for nearly forty years now. ICN is still embryonic and in its earlier stage of development. The idea of deploying it as the primary communication model for the Internet would not at all be a feasible task irrespective of the migration cost, risk, and difficulties. However, integrating a fractional part of ICN with DL on the Edge will improve the overall IoT performance and reliability, diminish the deployment complexity, and enhance the communication network flexibility.

Furthermore, the DL methods discussed in work can be extended in many IoT applications. Therefore, we propose to leverage a distributed DL approach in the impending works that can be used on various devices in a time-sensitive environment to reduce computation costs. RNN can facilitate a distributed model and can overcome the issue of processing huge data volumes. Recently developed Neural Network models are trained on large data sets that are capable of obtaining an efficient performance across a wide variety of domains in IoT but comes at a high cost. However, these models can estimate the data and learn abnormal behavior depending on the IoT devices and traffic.

V. CONCLUSION

This paper introduces multiple IoT application approaches based on deep learning models that aim to reduce latency for real-time-critical applications. Besides, we combine these DL models with ICN and EC. In the first part, we propose an approach based on CNN, that seeks to integrate ICN-IoT and edge computing. This approach's main advantage is to diminish the considerable amount of data produced by the multiple miscellaneous IoT devices. In the second part, to review the Cloud-based IoT data processing, we propose to develop another type of DL, i.e., recurrent neural network, which aims to preserve the history and predict future events.

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