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Deep Learning Techniques for Internet of Things (IoT) – A Survey

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Abstract: **- Recent advancements in Internet of Things (IoT) have emerged to exploit in many real world applications. Deep learning (DL) is gaining importance due to its incomparable analytics results and recommendations. The major challenge of IoT devices is availability of limited resource, which opens door for many researches on smart data processing and resource allocation. In this study, we provide an overview of DL techniques exploited for IoT domain. The study focuses on resource allocation and workload management for IoT data using DL techniques. We summarize recent researches that leveraged DL techniques in IoT domain. This survey covers IoT devices integrated with DL techniques for smart data process and resource allocation. We also study DL techniques incorporated on edge computing and cloud computing data centers for IoT applications.**

Keywords: - Internet of Things, Deep Learning, Edge Computing, Resource allocation, Workload management.

I. INTRODUCTION

Real world Internet of Things (IoT) evolves a revolution on not only traditional devices but also consumer connected devices such as TV, mobile phones, wearable, and other smart appliances. The innovation in wireless communication technologies boosts the demand for IoT technologies in many real world application areas. IoT involves exploiting internet connectivity on these devices and makes them advanced smart devices, which can interact over the internet to monitored and controlled. Limitations of IoT devices namely limited memory power, battery capacity, and processing capacity motivates us to study on resource allocation and work load management on these devices using deep learning techniques. The demand for IoT technologies in the major three fields of devices such consumer, enterprise and industrial and major domain namely transportation, agriculture, education, smart cities, retail etc., motivate many research on IoT. Among the many machine learning approaches, Deep Learning (DL) found to be incomparable for IoT applications.

Deep learning is used merely on data collected from IoT devices for further processing to bring some results on prediction or recommendation, whereas these techniques also exploited in resource allocation or workload management from IoT devices to edge or fog computing. We represent the overall architecture in Figure 1 for collecting data from IoT devices, allocating it to edge/fog resources and big data storage level on cloud.

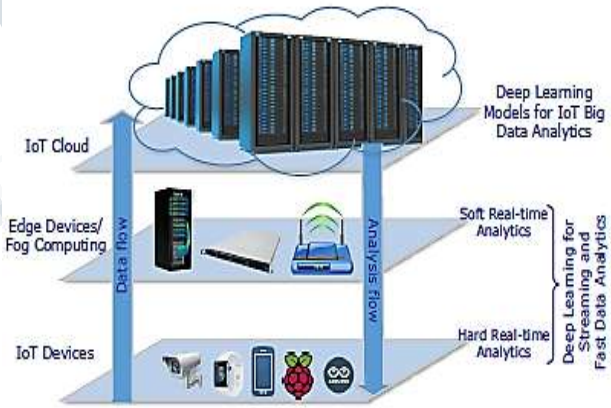

Figure: Overview of IoT and Deep learning model

Increasing number of smart IoT devices, the traffic in edge/fog cluster becomes heavy, resource allocation on these edge cluster need to implement to balance the load [1]. The number of IoT devices in real world applications is extremely huge, the data sharing between these devices and cloud server over large geographical areas is vital [3]. These devices are not all connected together, the data routing issue in resource allocation to be managed smoothly. High dynamics of IoT devices opt for highly managed dynamic resource allocation to handle network traffic in wireless communication technologies [1]. Edge or fog computing exploits the computation resource and also acts as a gateway to collect data from IoT devices

[2]. However, efficiently allocating the resource on edge cluster using deep DL techniques for resource limited IoT devices is challenging and studied recently in very few researches.

1.1 Survey Scope

Deep learning advancements in training and prediction explore many opportunities over traditional learning techniques. ML techniques needs hand crafted features by a domain experts, whereas DL techniques learn incrementally by hidden layer architecture from defining low-level and then to higher level categories. The features, which may not be noticeable by a domain expert, can be extracted easily by DL techniques. DL models represent reliable accuracy over traditional methods. The demand for Quality of Service (QoS) requirements, energy efficiency and performance improvements are to be considered in IoT applications. In this paper, we surveyed a wide range of Deep learning techniques for IoT applications, which improves above requirements on QoS. This survey aims to represent resource allocation and workload management on two main emerging technologies namely DL and IoT applications. Moreover this survey also focuses on resource allocation from IoT devices through edge/fog techniques then to cloud storage levels.

The remainder of this paper provides an overview of research handled in resource allocation and workload management of IoT devices using deep learning.

II. RESEARCH SURVEY

IoT devices with limited resources exploit light weight Operating Systems such as Contiki, TinyOS, and FreeRTOS, these OS are specially designed for IOT devices to support wide range of applications and operational prerequisites. The author in [4] discussed the advantages and limitations of OS resource management for IoT devices under various constrains such as process, memory, energy, communication and file management.

Existing studies lack in unawareness of Quality of Service (QoS) requirements of IoT applications, which motivated author in [5], they proposed deep learning inference model named “DeepRT”, given an input of QoS requirements such as deadline for inference deep learning and model compression bounds, it outputs inference service to an IoT applications.

Under existing techniques, Deep learning for data analysis and decision making is carried in centralized infrastructures this opens many challenges due to dynamic topology changes, high latency and network traffic in wireless networks. To overcome this problem, author in [6] exploited edge computing techniques to move the processing to edge of IoT devices namely smart phones, wearable, and other smart appliances, where data analysis, predictions and inference can be made without use of any centralized system. An efficient edge computing model should provide effective resource allocation and management between IoT devices and edge servers. However, selection of edge computing device under various networks is crucial problem, which is not attended in this study.

Appling Deep learning techniques in real world IoT devices with large amount dataset is a crucial problem, which even reduces the performance of devices. There was a need for efficient data processing to increase network reliability and device performance. In [7], author explored Singular- Value Decomposition (SVD)-QR algorithm for pre-processing the input data for deep learning algorithms. The author in turn used Limited Memory Subspace Optimization for SVD (LMSVD)-QR algorithm for large input of data to IoT devices. These techniques, they applied in handwritten character recognition and proved the data processing speed and reduced number of input to deep learning algorithm. However, extending SVD-QR algorithm for massive data processing systems is not attended.

Wireless Sensor is one of major area where IoT devices are widely used. These networks exploit Deep learning techniques to extract sensor data from IoT devices. Incrementally learning strategy of deep learning methods low-level and then to higher level categories and usage of hidden layer architecture ensures DL a promising data extraction techniques from sensor node devices. In [8], author explored work on sensor data extraction using DL techniques from IoT devices, in which they applied edge computing to offload data from effectively from sensor device edges. In this work, author evolved with a solution for problem that, as the DL techniques need large number of layer to process, there is a need for effective scheduling techniques. Network traffic can be reduced by allocating more layers in edge servers; however, edge server has limited processing capacity. Thus they proposed algorithms for optimization and maximization of number of allocated tasks in the edge computing server.

Software Defined Networking (SDN), another recent technology provides more reliability for IoT devices. Huge amount of data traffic from IoT devices influence SDN and IoT device performance. To overcome this problem, in [9], author applied efficient channel allocation techniques on SDN-IoT switch and avoided data traffic. Author exploits deep learning techniques on Partially Overlapping Channels (POC) assignment over SDN-IoT networks. Moreover, they used Deep Convolutional Neural Networks (Deep-CNN) to predict

the IoT traffic using past recorded IoT traffic patterns and channel assignment accordingly. However, bursty traffic allocation from heterogeneous devices is still an open challenge.

To improve the Quality of Service (QoS), the input traffic classification to be performed well for SDN network, this motivates another in [10]. As the IoT device has limited resource on memory and power, the traffic classification has to be performed in Virtualized Network Function (VNF) by applying Deep Neural Networks. Instead of choosing features based packet head and load, they used time relegated feature namely forward inter arrival time, backward inter arrival time, flow inter arrival time and active time for flow. These features make the system more reliable for traffic classification. However, this work has limitations when the traffic is unclassified, in such case Dijkstra's algorithm is used to find shortest path. Also the optimization of VNF placement to maintain high availability is not handled in this work.

Though the Quality of Service (QoS) improvements for IoT using deep learning techniques proposed by many authors, Quality of Experience (QoE) is unattended. This paved the way for author in [11] to exploit green computing for IoT devices. The communication between the network and user is considered in their case. Their work improves the network cost and Mean Opinion Score (MOS) of users of IoT devices. QoE parameter is arrived from QoENet to consider network cost and QoEUer to consider user MOS. As the IoT applications were used in real world are content centric application, they also focused on data caching strategies and cache allocation. In their work, efficient allocation of cache capacity using Deep Reinforcement Learning (DRL) is attempted.

Network latency is studied by many researchers, whereas back-haul bandwidth is an important parameter to be considered in fog enabled IoT devices. IoT devices enabled with fog computing to provide services to content centric networks is emerging, which motivates author in [12] to study further on content caching, computation offloading and resource allocation in fog enable IoT applications. Their work proves applying DNN on fog enabled IoT applications reduces network latency and back-haul bandwidth utilization. The author applied reinforcement learning (RL) to optimize and minimize end-to-end delay on decision making for wireless signals and service requests. In this part, they applied DNN to estimate functions values on decision making and also they applied DNN on actor side improve the stochastic policy.

Blockchain, an emerging technique nowadays exploited in IoT device applications. The limited resource of IoT devices may not allow deep learning process to be handled in devices itself, thus Edge computing is utilized to perform necessary mining techniques. Traditional auctions carried out based on first-price and second-price, which provides revenue gain Edge Computing Service Provider (ECSP). However, no method is proposed to maximize revenue ECSP and incentive compatibility for user rationality. This problem motivated author in [13] to go for edge resource allocation, their system delivers an optimal auction using deep learning. In specific, their work involves, DNN to learn auction mechanism to arrive an optimal auction and conditional payment rules.

Visual Internet of Things (VIoT) exploits deep learning techniques in vast, these networks handles images in large quantity, also the original image size is too high to handle for IoT devices. Authors, in [14] motivated by such a network, they proposed hybrid cross deep network (HCDN) to classify images, HCDN is trained by different visual sensors. HCDN is trained by all images from one visual sensor and limited images from another visual sensor. User testing model, features are extracted from trained HCDN for transmission, storage and classification. HCDN requires less storage capacity than the original image. However, handling the visual image is a challenging task.

Mobile edge computing (MEC) is an emerging area of study for IoT devices, these techniques provides computation on mobile edge and provides energy harvesting. Authors in [15] proposed MEC model for IoT devices to offload the computation to mobile edge, in which deep learning model CNN is used to calculate offloading cost, battery level etc., and predicted harvested energy.

III. CONCLUSIONS

Fast growing demand for smart IoT devices in real world application motivated us to propose this survey. There are many existing work reported in using Deep Learning techniques for IoT techniques, we surveyed some of them. We referred some of the work in providing Quality of Service (QoS) and Quality of Experience (QoE) in IoT application using CNN techniques. Few papers are discussed based on Software defined Networking (SDN) for IoT devices, which provides Virtualized Network Function (VNF) and Channels assignment. Visual Internet of Things (VIoT) is used in many real world application such as face detection, traffic sign detection, vehicle tracking, etc., uses deep learning techniques for image classification and thus to reduce storage usage. Our future direction of work is to identify a specific problem in resource and workload management using Deep learning in IoT applications.

REFERENCES

[1] Fengxiao Tang, Zubair Md. Fadlullah, Bomin Mao, and Nei Kato, "An Intelligent Traffic Load Prediction Based Adaptive Channel Assignment Algorithm in SDN-IoT: A Deep Learning Approach" IEEE Internet of Things Journal, May 2018.

[2] Zhuoran Zhao , Kamyar Mirzazad Barijough, and Andreas Gerstlauer, "DeepThings: Distributed Adaptive Deep Learning Inference on Resource-Constrained IoT Edge Clusters", IEEE transactions on Computer-Aided Design of Integrated Circuits and Systems, vol. 37, no. 11, November 2018

[3] Yue Xu, "Recent Machine Learning Applications to Internet of Things (IoT)", Recent Machine Learning Applications to Internet of Things (IoT)

[4] Arslan Musaddiq, Yousaf Bin Zikria, Oliver Hahm, Heejung Yu, Ali Kashif Bashir And Sung Won Kim, "A Survey on Resource Management in IoT Operating Systems", IEEE Access, Volume: 6, February 2018, pages 8459 – 8482.

[5] Woochul Kang and Daeyeon Kim, "DeepRT: A Predictable Deep Learning Inference Framework for IoT Devices", 2018 IEEE/ACM Third International Conference on Internet-of-Things Design and Implementation.

[6] Hesham El-Sayed, Sharmi Sankar, Mukesh Prasad, Deepak Puthal, Akshansh Gupta, Manoranjan Mohanty, And Chin-Teng Lin, "Edge of Things: The Big Picture on the Integration of Edge, IoT and the Cloud in a Distributed Computing Environment", IEEE Access, Volume:6, pages 1706 – 1717.

[7] Stephen D. Liang, "Smart and Fast Data Processing for Deep Learning in Internet of Things: Less is More", IEEE Internet of Things Journal, Pages 1-1, August 2018.

[8] He Li, Kaoru Ota, and Mianxiong Dong, "Learning IoT in Edge: Deep Learning for the Internet of Things with Edge Computing", IEEE Network Volume: 32 , Issue: 1 , Jan.-Feb. 2018 , Pages: 96 – 101.

[9] Fengxiao Tang, Bomin Mao, Zubair Md. Fadlullah, and Nei Kato, "On a Novel Deep-Learning-Based Intelligent Partially Overlapping Channel Assignment in SDN-IoT", IEEE Communications Magazine, Volume: 56, Page(s): 80 – 86, Issue: 9 , Sept. 2018

[10] Jun Xu, Jingyu Wang, Qi Qi, Haifeng Sun, Bo He, "Deep neural networks for application awareness in SDN-based network", IEEE 28th International Workshop on Machine Learning for Signal Processing (MLSP), September 2018.

[11] Xiaoming He, Kun Wang, Huawei Huang, Yixuan Wang, and Song Guo, "Green Resource Allocation based on Deep Reinforcement Learning in Content-Centric IoT", IEEE Transactions on Emerging Topics in Computing, February 2018.

[12] Yifei Wei, F. Richard Yu, Mei Song, and Zhu Han, "Joint Optimization of Caching, Computing, and Radio Resources for Fog-Enabled IoT Using Natural Actor-Critic Deep Reinforcement Learning", IEEE Internet of Things Journal, October 2018.

[13] Nguyen Cong Luong, Zehui Xiong, Ping Wang, and Dusit Niyato, "Optimal Auction For Edge Computing Resource Management in Mobile Blockchain Networks: A Deep Learning Approach", IEEE International Conference on Communications (ICC), 2018.

[14] Zhong Zhang, Donghong Li, "Hybrid Cross Deep Network for Domain Adaptation and Energy Saving in Visual Internet of Things", IEEE Internet of Things Journal, June 2018.

[15] Minghui Min, Dongjin Xu, Liang Xiao, Yuliang Tang, Di Wu, "Learning-Based Computation Offloading for IoT Devices with Energy Harvesting", Networking and Internet Architecture, 2017.