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End to End Wireless Communication System Based on Classification Techniques: Survey and Discussions

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ABSTRACT

Recent research in the design of end to end communication system using deep learning has produced models which can outperform traditional communication schemes. The aim of any communication system is to perfectly reproduce the message at the receiver sent by a transmitter through a channel between the sender and receiver. Due to the noise characteristics of the channel, the transmitted signal can get corrupted, and the exact reconstruction of the message may not happen at the receiver. In this paper our survey explores the crossovers and the integration of wireless communication and Neural network and Classification technology, aims at solving specific issues in the mobile networking domain, and greatly improve the performance of wireless communication systems.

Keywords:- Wireless sensor network, Deep learning, Internet of Things, Cognitive radio, Primary user, Secondary user.

INRODUCTION

Our society is undergoing a digitization revolution, with a dramatic increase of both Internet users and connected devices. The fifth generation of wireless communication networks will be rolled out shortly, featuring innovative technologies such as infrastructure densification, antenna densification, use of frequency bands in the mmWave range, energy-efficient network management [9].

It is of paramount importance to deliver information in wireless medium from one point to another quickly, reliably, and securely. Wireless communications is a field of rich expert knowledge that involves designing waveforms (e.g., long-term evolution (LTE) and fifth generation mobile communications systems (5G)), modeling channels (e.g., multipath fading), handling interference (e.g., jamming) and traffic (e.g., network congestion) effects, compensating for radio hardware imperfections (e.g., RF front end nonlinearity), developing communication chains (i.e., transmitter and receiver), recovering distorted symbols and bits (e.g., forward error correction), and supporting wireless security (e.g., jammer detection). The design and implementation of conventional communication systems are built upon strong probabilistic analytic models and assumptions. However, existing communication theories exhibit strong limitations in utilizing limited spectrum resources and handling the complexity of optimization for emerging wireless applications (such as spectrum sharing, multimedia, Internet of Things (IoT), virtual and augmented reality), each with high degrees of freedom.

These smart communication systems rely on various detection, classification, and prediction tasks such as signal detection and signal type identification in spectrum sensing to increase situational awareness. To achieve the tasks set forth in this vision, machine learning (especially deep learning) provides powerful automated means for communication systems to learn from spectrum data and adapt to spectrum dynamics [7]. Thus future wireless networks will be characterized by an unprecedented level of complexity, which makes traditional approaches to network deployment, design, and operation no longer adequate.

Moreover, future wireless communication systems will become ever-more demanding for edge-cloud computing since the edge servers are in proximity of the IoT devices and communicate with them via different wireless communication technologies. The requirements of high bandwidth and low latency for wireless communications have posed enormous challenges to the design, configuration, and optimization of next-generation networks (NGN). In the meantime, massive multiple input multiple-output (MIMO) is widely regarded as a major technology for future wireless communication systems. In order to improve the quality of wireless signal transmission, the system uses multiple antennas as multiple transmitters at the base station (BS) and receivers at a user equipment (UE) to realize the multipath transmitting, which can double the channel capacity without increasing spectrum resources or antenna transmit power. However, conventional communication systems and theories exhibit inherent limitations in the utilization of system structure information and the processing of big data. Therefore, it is urgent to establish new communication models, develop more effective solutions to address such complicated scenarios and further fulfill the requirements of future wireless communication systems, e.g., beyond the fifth-generation (B5G) networks [2].

Machine Learning is a subfield of artificial intelligence (AI) that provides a system with the ability to automatically learn and improve from experience without explicitly programming that system to do it. The learning process begins with the use of data, such as examples, direct experience or instruction, so as to look for patterns in data and perform better in the future based on the data provided. Several approaches to the application of machine learning (ML) in telecommunications have been made in the last years. With the emergence of deep learning (DL), researchers have started to work towards its application in communications networks. Among the applications of deep learning in communications, which is an emerging field, there is a technique called end-to-end learning which aims at learning transmitter and receiver architectures to properly communicate under any imperfection or intractability of the channel. Concretely, end-to-end learning can be applied to solve the problem of constellation design in the context of intractable channel models [5].

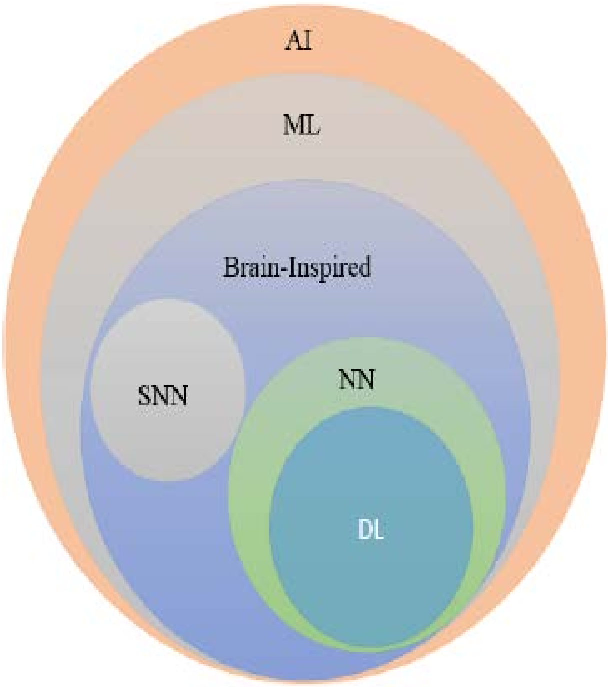

Fig 1. AI: Artificial Intelligence, ML, NN, DL, and Spiking Neural Networks (SNN).

Deep Learning is a new branch of machine learning that makes use of neural networks, a concept which dates back to 1943 [4] to find solutions for a variety of complex tasks. Neural networks were inspired by the way the human brain learns to show that distributed artificial neural networks could also learn nontrivial tasks, even though current architectures and learning procedures are far from brain-like behavior. Algorithmic breakthroughs, the feasibility of collecting large amounts of data, and increasing computational power have contributed to the current popularity of neural networks, in particular with multiple (deep) hidden layers, that indeed have started to outperform previous state-of-the-art machine learning techniques. Unlike conventional machine learning approaches, deep learning needs no feature engineering of inputs since the model itself extracts relevant features on its own and defines which features are relevant for each problem. Deep learning models perform extremely well with correlated data, which contributed to substantial improvements in computer vision, image processing, video processing, face recognition, speech recognition, text-to-speech systems and natural language processing. Deep learning has also been used as a component in more complex systems that are able to play games or diagnose and classify diseases [4].

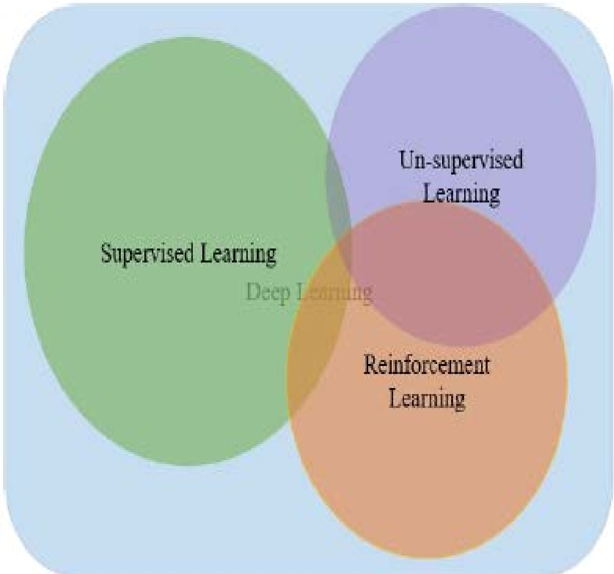

Fig 2. Category of Deep Leaning approaches [6].

II END-TO-END COMMUNICATIONS

The guiding principle in communication system design is to decompose signal processing into chains with multiple independent blocks [2]. Each independent block performs a well-defined and isolated function, such as source coding/decoding, channel coding/decoding, modulation, channel estimation and equalization. This kind of approach yields today's efficient, versatile, and controllable wireless communication systems. However, it is unclear whether the optimization of individual processing blocks can achieve optimal end-to-end performance, while deep learning can realize theoretically global optimal performance. Thus, deep learning has produced far-reaching significance for wireless communication systems and has shown promising performance improvements. In addition, the idea of end-to-end learning in communication systems has also attracted widespread attention in the wireless communications community. Several emerging trends for deep learning in communication physical layer were elaborated in. By treating the wireless communication system as an auto encoder, redefining it as the transmitter and receiver, a local optimum of the end-to-end refactoring process can be achieved.

III RELATED WORK

[1] In this article, they develop an end-to-end wireless communication system using deep neural networks (DNNs), where DNNs are employed to perform several key functions, including encoding, decoding, modulation, and demodulation. However, an accurate estimation of instantaneous channel transfer function, i.e., channel state information (CSI), is needed in order for the transmitter DNN to learn to optimize the receiver gain in decoding. This is very much a challenge since CSI varies with time and location in wireless communications and is hard to obtain when designing transceivers. They propose to use a conditional generative adversarial net (GAN) to represent channel effects and to bridge the transmitter DNN and the receiver DNN so that the gradient of the transmitter DNN can be back-propagated from the receiver DNN. [2] In this paper author mainly reviews the latest research progress and major technological deployment of deep learning in the development of wireless communications. They highlight the intuitions and key technologies of deep learning-driven wireless communication from the aspects of end-to-end

communication, signal detection, channel estimation and compression sensing, encoding and decoding, and security and privacy. Main challenges, potential opportunities and future trends in incorporating deep learning schemes in wireless communications environments are further illustrated. [3] In this tutorial author start the paper by addressing the questions of why and when such techniques can be useful. It then provides a high-level introduction to the basics of supervised and unsupervised learning. For both supervised and unsupervised learning, exemplifying applications to communication networks are discussed by distinguishing tasks carried out at the edge and at the cloud segments of the network at different layers of the protocol stack, with an emphasis on the physical layer. This paper provides a very brief introduction to key concepts in machine learning and to the literature on machine learning for communication systems. [4] In this work they propose and implement a novel class of active inference attacks on deep neural networks in a collaborative setting. Their approach relies on Generative Adversarial Networks (GANs) and is more effective and general than existing information extraction mechanisms. They believe our work will have a significant impact in the real world as major companies are considering distributed, federated, or decentralized deep learning approaches to protect the privacy of users. The main point of their research is that collaborative learning is less desirable than the centralized learning approach it is supposed to replace. In collaborative learning, any user may violate the privacy of other users in the system without involving the service provider. [5] In this paper, they make a brief survey about machine learning techniques and end-to-end learning. End-to-end learning consists of a technique in which full transmitter and receiver architectures based on DNNs can be learned. They present the different ways to perform the training of end-to-end learning and some cases in which end-to-end learning has been used for constellation design. [6] This report presents a brief survey on the advances that have occurred in the area of DL, starting with the Deep Neural Network (DNN). The survey goes on to cover the Convolutional Neural Network (CNN), the Recurrent Neural Network (RNN) including Long Short Term Memory (LSTM) and Gated Recurrent Units (GRU), the Auto-Encoder (AE), the Deep Belief Network (DBN), the Generative Adversarial Network (GAN), and Deep Reinforcement Learning (DRL). Additionally, they have included recent developments such as advanced variant DL techniques based on these DL approaches. They also included recently developed frameworks, SDKs, and benchmark datasets that are used for implementing and evaluating deep learning approaches. There are some surveys that have been published on Deep Learning using Neural Networks. [7] In this chapter, they first describe how deep learning is used to design an end-to-end communication system using auto encoders. This flexible design effectively captures channel impairments and optimizes transmitter and receiver operations jointly in single-antenna, multiple-antenna, and multiuser communications. Next, they present the benefits of deep learning in spectrum situation awareness ranging from channel modeling and estimation to signal detection and classification tasks. Deep learning improves the performance when the model-based methods fail. Finally, they discuss how deep learning applies to wireless communication security. [8] In this work they provide a framework to design end to end communication systems which accounts for the existence of noise corrupted transmit symbols. The proposed method uses deep neural architecture. An objective function for optimizing these models is derived based on the concepts of variational inference. Further, domain knowledge such as channel type can be systematically integrated into the objective. Through numerical simulation, the proposed method is shown to consistently produce models with better packing density and achieving it faster in multiple popular channel models as compared to the previous works leveraging deep learning models. [9] This work deals with the use of emerging deep learning techniques in future wireless communication networks. It will be shown that data-driven approaches should not replace, but rather complement traditional design techniques based on mathematical models. Extensive motivation is given for why deep learning based on artificial neural networks will be an indispensable tool for the design and operation of future wireless communication networks, and our vision of how artificial neural networks should be integrated into the architecture of future wireless communication networks is presented. [10] In this paper, a novel experienced deep reinforcement learning (deep-RL) framework is proposed to provide model-free resource allocation for ultra reliable low latency communication (URLLC) in the downlink of a wireless network. The proposed, experienced deep-RL framework can guarantee high end-to-end reliability and low end-to-end latency, under explicit data rate constraints, for each wireless user without any models of or assumptions on the users' traffic. In particular, in order to enable the deep-RL framework to account for extreme network conditions and operate in highly reliable systems, a new approach based on generative adversarial networks (GANs) is proposed. This GAN approach is used to pre-train the deep-RL framework using a mix of real and synthetic data, thus creating an experienced deep-RL framework that has been exposed to a broad range of network conditions. [11] In this paper, a DL-based channel estimator is designed under the time varying Rayleigh fading channel. The proposed DL-based channel estimator can achieve better performance than traditional algorithms and some NN estimators with different structures. Besides, the proposed NN channel estimator shows its ability to dynamically track the channel and its robustness with pilot density. The simulation results show the proposed NN estimator has better Mean Square Error (MSE) performance compared with the traditional algorithms and some other DL-based architecture. Furthermore, the proposed DL-based estimator also shows its robustness with the different pilot densities.

IV PROBLEM IDENTIFICATION

The fundamental problem of communication systems is to transmit a message such as a bit stream from a transmitter using radio waves and reproduce it either exactly or approximately at a receiver. The focus in this section is on the physical layer of the Open Systems Interconnection (OSI) model. Conventional communication systems split signal processing into a chain of multiple independent blocks separately at the transmitter and receiver, and optimize each block individually for a different functionality. The communication channel distorts and attenuates the transmitted signal. Furthermore, noise is added to the signal at the receiver due to the receiver hardware impairments. Each communication block at the transmitter prepares the signal to the negative effects of the communication medium and receiver noise while still trying to maximize the system efficiency. These operations are reversed at the receiver in the same order to reconstruct the information sent by the transmitter. A communication system consists of a transmitter, a receiver, and channel that carries information from the transmitter to the receiver. A fundamental new way to think about communication system design is to formulate it as an end-to-end reconstruction task that seeks to jointly optimize transmitter and receiver components in a single process using autoencoders.

V CONCLUSION AND FUTURE SCOPE

In this paper we review the various classification techniques of wireless communication. We gather, investigate and analyze latest research works in emerging deep learning methods for processing and transferring data in the field of wireless communications or related scenarios, including strengths and weaknesses. The main focus is on how to customize deep learning for mobile network applications from three perspectives: mobile data generation, end-to end wireless communications and network traffic control that adapts to dynamic mobile network environments. In future we develop the end to end reliable communication and enhance the performance of wireless system.

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