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# Applications of artificial intelligence for the system architecture in the optical networks

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**Abstract:** The telecoms industry, which uses artificial intelligence extensively, is one of the most profitable industries due to the supply of high-quality services to customers. The telecoms sector has advanced in recent years as a result of the technological revolution and digital transformation. Telecommunications companies not only provide network infrastructure and data transmission, but also artificial intelligence-based computing and big data. Machine learning's application in communication networks is still in its early phases. This might be because a considerable infrastructure must be in place before network data can be efficiently absorbed by ML applications. Furthermore, the development of machine learning infrastructure and applications needs a new set of multidisciplinary skills that have not traditionally been readily available in the industry.

**Keywords:** artificial intelligence, machine learning, optical networks, system architecture, intelligent management

## INTRODUCTION

In 1956, during the Dartmouth Conference in the United States, the concept of artificial intelligence was first suggested [1]. Artificial intelligence gradually made its way throughout society and into research labs. The rapid development of intelligent gadgets, the complexity of algorithms, and the assistance of massive data have all accelerated the development of artificial intelligence since 2000, particularly after 2015. Artificial intelligence has been employed in a variety of fields so far. Many enterprises and organizations all around the world accept artificial intelligence guides and guidelines. Modern robots and self-driving vehicles are examples of artificial intelligence.

The telecoms industry, which uses artificial intelligence extensively, is one of the most profitable industries due to the supply of high-quality services to customers. The telecoms sector has advanced in recent years as a result of the technological revolution and digital transformation. Telecommunications companies not only provide network infrastructure and data transmission, but also artificial intelligence-based computing and big data.

The rapid development of technologies such as cloud computing, deep learning, and big data in recent years has paved the way for the application of artificial intelligence solutions in various fields.

This, in turn, led to the emergence of SDN (software-defined networks) and NFV (network functions virtualization), as well as intelligent communication networks and services [2].

The sharp increase in the number of wireless traffic models and network elements of telecommunications networks has been characterized by the widespread popularity of smartphones. Through the development and introduction of SDN and NFV technologies, network management has gained some clarity. For example, virtualization can be done not only at the level of the network element, but also at the level of the CPU, memory, port and bandwidth.

The network and its elements are heterogeneous. Users typically use different devices in different wireless network standards, such as 2G, 3G, 4G, and Wi-Fi. Also, the introduction of the 5G standard will inevitably lead to significant changes in the telecommunications network. Given the above factors, it can be seen that the management and provision of service quality (QoS) in networks is becoming increasingly complex.

## LITERATURE REVIEW

### A. CONCEPT OF ARTIFICIAL INTELLIGENCE

Artificial intelligence and the first artificial intelligence hypothesis evolved in the mid-twentieth century, following the early twentieth-century boom in computing technology [3]. At the Dartmouth Conference in the United States in 1956, John McCarthy developed the term "artificial intelligence" [1]. Artificial intelligence was once supposed to be the act of utilizing a computer to create a complicated machine that resembled human intelligence in important ways. Artificial intelligence's definition evolved through time. Shenoy [4], for example, characterizes artificial intelligence as a perplexing discipline of computer science. Artificial intelligence, according to Rich and Knight [5], is given by machines and differs from natural intelligence displayed by people. Artificial intelligence involves driving computers to function as intelligently as people. Artificial intelligence, according to Nilsson [6], is one of the disciplines of informatics concerned with ensuring the intellectual complexity of computers. Kasemsap [7] is a branch of research that aids artificial intelligence computers in figuring out the best way to solve complicated human-like situations.

Because it incorporates computing, cognition, reasoning, and action, Pannu [8] claims that artificial intelligence is neither psychology nor computer science. Artificial intelligence, he claims, has benefits over natural intelligence because it is more consistent, consistent, less expensive, easier to replicate and disseminate, and can record and complete tasks faster than people.

Despite the fact that scientists describe artificial intelligence in a variety of ways, they all agree that it encompasses computer science, information engineering, mathematics, psychology, linguistics, and philosophy. When it comes to chess, artificial intelligence now outperforms humans. People, on the other hand, are still superior at comprehending and studying visuals [8-9]. When the name and goal of artificial intelligence were specified in 1956, it became an academic discipline.

Artificial intelligence's major goal is to enable robots to execute complicated activities that would normally need the use of a human brain. Philosophy, logic theory, and science fiction impacted early artificial intelligence research [10]. Artificial intelligence's directions later evolved into applications, impacts, and applications. According to CAICT and Gartner [11], the development of artificial intelligence includes three stages, as shown in Figure 1: Early Stage (1956-1980), Industrialization (1980-2000), and Development (2000). -2018).

Artificial intelligence research has begun in earnest. McCarthy [12], for example, emphasized the role of artificial intelligence. In 1969, the International Federation of Artificial Intelligence (IFAI) was created, with its inaugural congress held in Seattle, Washington. Although artificial intelligence is still in its infancy, the number of artificial intelligence research and applications has been continuously expanding. Furthermore, the understanding of artificial intelligence has grown in breadth and depth.

Artificial intelligence has entered the manufacturing phase in many industrialized nations during the industrialization era. For Digital Equipment Corporation (DEC), the second biggest computer manufacturer in the United States at the time, Carnegie Mellon University created the XCON (eXpert CONfigurer) in 1980. Businesses have saved $ 40 million every year since the debut of XCON [13]. IBM began work on the Deep Blue-niv, a chess supercomputer with artificial intelligence, in 1985, and it took 12 years to complete.

Deep Blue defeated global chess champion Harry Kasparov on May 11, 1997. This was a watershed moment in the history of artificial intelligence. The creation of artificial intelligence, on the other hand, is not limited to the United States. In 1982, Japan committed $ 850 million in the development of artificial intelligence computers, with the goal of creating a strong PROLOG machine [14]. Germany founded the Artificial Intelligence Research Centre in 1988, which was at the time the world's largest non-profit research centre.

During the development phase, equipment, particularly sensors and processors, as well as massive data, will aid artificial intelligence development. Artificial intelligence is now being employed in a variety of solutions and advancements, including contemporary robots, self-driving vehicles, and smart computers [15]. According to Clark [16], between 2012 and 2015, the number of software projects at Google that included artificial intelligence increased dramatically. DeepMind beat Lee Sedol, the former world champion in Go, in 2016 [9]. Because Go is a more complicated game than chess, AlphaGo's achievement is significant in the development of artificial intelligence. Artificial intelligence algorithms can now outperform humans due to enhanced computer infrastructure.

## B. MACHINE LEARNING IN TELECOMMUNICATIONS

Machine learning (ML) is the capacity of artificial intelligence (AI) systems to gain their own knowledge by finding patterns from raw data [17-18]. This method has been demonstrated to work for an increasing range of applications, spanning from image recognition to natural language processing and others [18]. It is based on classical linear algebra [19] and probability theory [20]. When dealing with large volumes of data, sometimes known as "big data," machine learning is highly effective.

Larger datasets enable more accurate learning during ML training; these datasets are too huge for the human eye to absorb, but can be scanned by computers running ML algorithms. The early 2000s [21] and 2010s [22-23] searches for subatomic particles are notable instances of this ML Big Data synergy. Deep learning [24] is now largely accepted as the state-of-the-art in the discipline. A deep convolutional neural network won a prominent image recognition competition (ILSVRC, a.k.a. "ImageNet") by a considerable margin in 2012 [25]. At the same tournament in 2015, superhuman performance was reached for the first time [26].

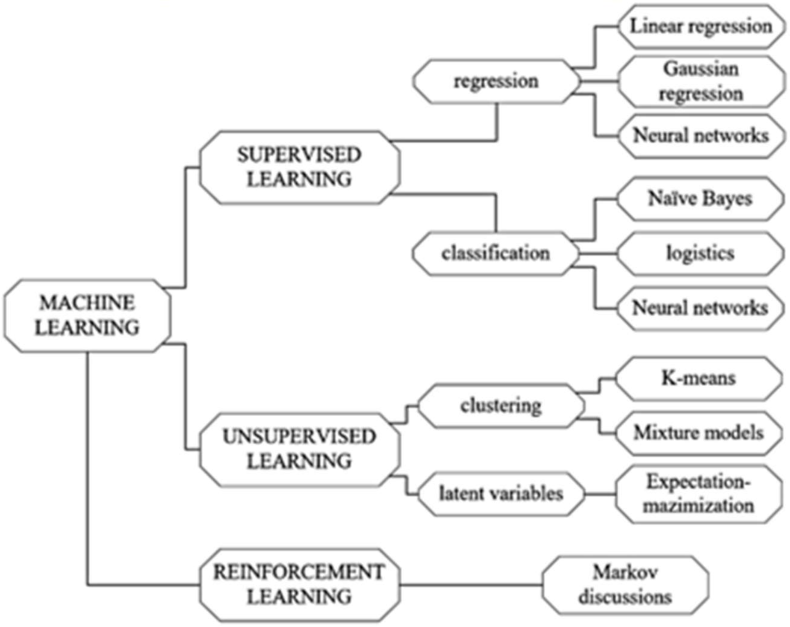

**Figure 1 Conceptual overview of the Machine learning algorithms**

Using deep reinforcement learning, AlphaGo Zero attained superhuman performance in the ancient Chinese game of Go without any human input in 2017 [27]. Last but not least, the use of machine learning applications has proven extremely beneficial for technological businesses such as Google, Microsoft, Facebook, IBM, Baidu, Apple, Netflix, and others during the last decade. As a result, it is now clear that ML not only works technically, but also has economic value.

There is no question that ML technologies can be successfully used to communication networks. Optical networks are made up of thousands of network pieces in most cases (NEs). For packet, IP, mobile, or "Internet of Things" networks, this number rises dramatically. These NEs generate a tremendous quantity of data that ML may use. In addition, multi-layer, multi-vendor telecommunications networks quickly become extremely complicated. ML applications can help handle this complexity.

## MACHINE LEARNING APPLICATIONS IN COMMUNICATION NETWORKS SUPPORTED BY INFRASTRUCTURE

Machine learning's application in communication networks is still in its early phases. This might be because a considerable infrastructure must be in place before network data can be efficiently absorbed by ML applications. Furthermore, the development of machine learning infrastructure and applications needs a new set of multidisciplinary skills that have not traditionally been readily available in the industry. Despite this, network service providers (AT&T, Verizon, and others), private network operators (Google, Facebook, and others), and network equipment suppliers (Ciena, Cisco, and others) are all experimenting with machine learning programs geared at communication networks.

More infrastructure is needed to manage the huge variety, amount, and/or velocity of “Big” data in order to take advantage of ML-Big Data synergies. Wide variation necessitates a layer of abstraction between the raw inputs from many sources and the machine learning algorithms (this is also referred to as a "Resource Adapter"). Large amounts of data necessitate dispersed storage and parallel computation on a computer cluster (sometimes known as a "data lake" or "cloud").

It also need a fast technique for reading and processing large quantities of data. The software tools Apache Hadoop and Apache Spark are often used to do this. Finally, data-streaming capabilities are required for high velocity. Adding technologies like Apache Kafka to the Hadoop/Spark cluster can help with this.

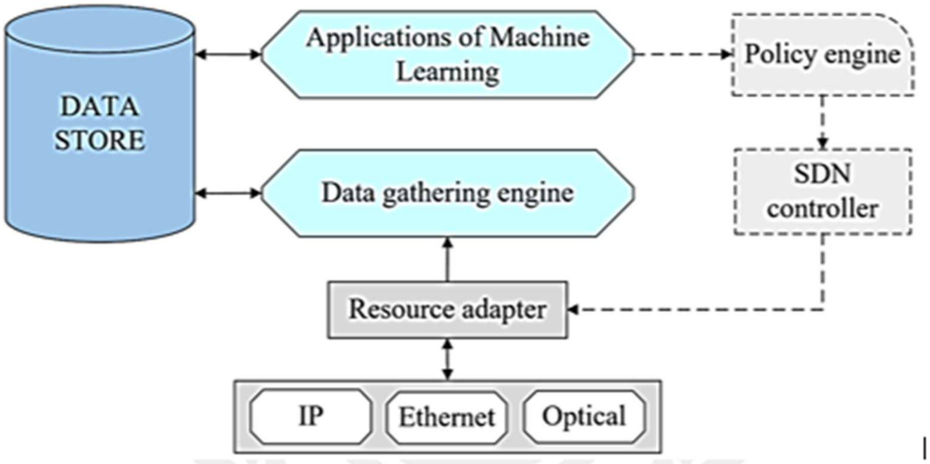

**Figure 2 Machine learning applications in communication networks supported by infrastructure**

Figure 1 depicts the whole infrastructure required to enable ML-driven communication network applications. For read-only applications, solid lines are essential. A data collecting engine, a data lake, a series of machine learning applications, and an SDN-aware network are all part of it. The policy engine is an optional interface that separates the insights supplied by the apps from the actions taken on the network as a result of those insights.

## PROPOSED INTELLECTUAL SYSTEM ARCHITECTURE APPLYING MACHINE LEARNING IN OPTICAL NETWORKS

The concepts of using machine learning to solve optical network challenges are summarized in this section. Furthermore, the incentives for using ML are examined in depth, starting with features of inherent ML features and optical network improvements that might allow ML applications.

Figure 2 depicts the system architecture of optical networks including ML (a). An intelligent module made up of Functional Elements (FEs) and ML agents should be placed in optical networks to use ML-based approaches.

The FEs are in charge of the information exchange between the ML agent and the physical optical networks. The Data Collection module of FEs takes raw data from the optical network, and the Data Processing module pre-processes it into a data format that ML models can understand.

Network protocols and functions must be changed to allow FE on network data collection [28] and data processing. The gathered and pre-processed network data, as well as network status information from FEs, will be used to train ML agents. An ML agent in an optical network can operate in one of three modes: regression, classification, or decision-making. The workflows of these three paradigms are depicted in Figure 2.

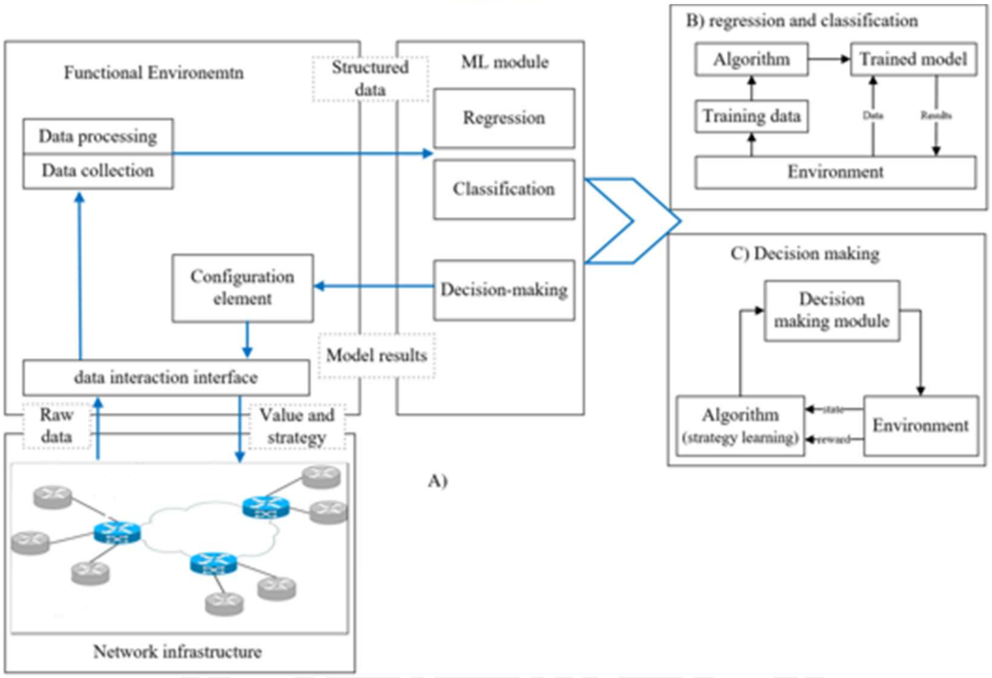

**Figure 3 Proposed intellectual system architecture applying Machine learning in optical networks**

Supervised and unsupervised learning are commonly used to tackle regression and classification issues. The ML model parameters are defined and repeatedly refined using learning methods and training datasets, as illustrated in Fig. 2 (b). Learning algorithms, such as Sequential Minimal Optimization (SMO) for Support Vector Machines (SVM) and backpropagation for neural networks [29], are approaches that enhance model performance under a certain measure. In optical networks contexts, well-trained ML models are employed with features as input and output the regression and classification results.

As illustrated in Fig. 2, in decision-making tasks, ML models develop the best approach by interacting with the environment (optical network) (c). When an action is performed in an optical network environment, the learning algorithm receives a reward depending on the action's performance, and the strategies that a decision-making agent creates are changed depending on the reward. For optimum strategy learning, there is an iteration loop. Under a particular set of circumstances, the learnt optimum strategy determines which action to take. Reinforcement learning is frequently used in decision-making situations.

## CONCLUSION

Using ML in optical networks as an inter-disciplinary mix is a viable technique to improving optical network performance. Existing research on machine learning for intelligent optical networks is covered in this study. We'll start by going through the history and problems of today's communication and optical networks. Following that, three ML paradigms (regression, classification, and decision-making) are thoroughly described. The motivations for employing machine learning to develop intelligent optical networks are examined in terms of both inherent ML algorithm properties and external enabling approaches. Then, the use of machine learning methods in optical networks is examined. ML application cases in optical networks are examined in the major portion of this investigation, which is divided into two categories: optical network control and resource management, and optical network monitoring and survivability.

Finally, we highlight obstacles that future applications of machine learning for intelligent optical networks may confront, as well as potential solutions to each obstacle. In conclusion, introducing intelligence into optical networks is difficult, and interest in using machine learning to intelligent optical networks is growing. This study looks at how machine learning techniques have been used and should be utilized in optical networks. We think that our debate and investigation would make it easier for academics to use machine learning in future intelligent optical networks.

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