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Xhafer Krasniqi
University for Business and Technology, xhafer.krasniqi@ubt-uni.net

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Krasniqi, Xhafer, "AI leverage in easing the 5G complexity and enhancing 5G intelligent connectivity" (2019). *UBT International Conference*. 278.
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AI leverage in easing the 5G complexity and enhancing 5G intelligent connectivity

Xhafer Krasniqi

UBT – Higher Education Institution, Lagjja Kalabria, 10000 p.n., Prishtine, Kosovo

Abstract. As 5G era is approaching fast and pre-commercial 5G tests and trials are happening everywhere around the world, one of the key challenges for carriers and 5G providers is to maintain and operate the network complexity required to meet diverse services and personalized user experience requirements. This maintenance and operation have to be smarter and more agile in 5G than it was in previous generations. AI and ML can be leveraged in this case to ease 5G complexity and at the same time enhance the intelligent connectivity between diverse devices and tiny end points, e.g. IoT sensors.
Machine learning and AI algorithms can be used to digest and analyse cross-domain data that would be required in 5G in a much more efficient way enabling quick decision and as such easing the network complexity and reducing the maintenance cost. The cross-domain data includes geographic information, engineering parameters and other data to be used by AI and ML to better forecast the peak traffic, optimize the network for capacity expansion and enable more intelligent coverage through dynamic interference measurements.
This paper provides an overview of 5G complexity due to its heterogenous nature and the key role of AI and ML to ease this complexity and enhance the intelligent connectivity between diverse devices with different requirements. The focus of this paper will be on the key aspects of AI and ML application in 5G and the key benefits from this application. Finally, this paper will analyse the overall performance of 5G in terms of coverage and latency compared with traditionally operated networks.

Keywords: 5G, AI, ML, IoT, Sensors, Network Slicing, Virtualisation, MTC.

Introduction

There is no doubt that 5G is expected to be a complex network since it will be the main mechanism for transporting the avalanche of data generated by billions of devices and IoT sensors connected through 5G. Having to handle all of this data and huge number of connected devices will add further to the complexity of 5G and the chaos brought by 5G and as such would require a new technology that would help handling this data and would make sense of this complexity and chaos. This new technology needed and required by 5G is AI. On the other side, AI will also need 5G and its massive data in order for the AI to be successful and enhance the AI algorithm. The more data sets that are used as inputs to machines learning the more accurate the outcome patterns will be.

5G Network

5G is the latest cellular network generation that is currently under development and still at an infancy stage. It is going through a number of pre-commercial tests and trials and it is at an early adoption stage with a very limited coverage. It has been deployed by a number of operators, but this is only the early version of it, the LTE-based
5G or also known as NSA (Non-StandAlone) implementation.
5G network is very heterogeneous in nature and it is a platform that interacts with different networks and different radio technologies that serve various devices with different resource requirements, as shown in the figure below.

Figure 1, 5G heterogeneity

5G Complexity

Main things that would make 5G complex and would differentiate it from other previous networks in terms of complexity are the heterogeneity of 5G, its network topology, design and propagation models together with user's mobility and usage patterns. Some or all of these parameters were also part of the previous networks and generations, but not in the same scale as 5G.
5G aims to address three major requirements as shown in the diagram below:

- Massive broadband (eMBB)
  - In the range of 10 Gbps
- Very high number of connections (mMTC)
  - In the range of a million per km2
- Extremely reliable and low latency (uRLLC)
  - In the range of 1 ms

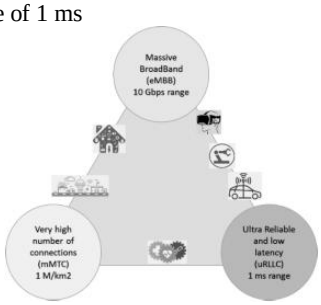

Figure 2, 5G requirements

AI

AI is the science of training systems to emulate human tasks through learning and automation. AI is not a new technology since it has been around since the 1950s, but it is only recently finding its place in mainstream applications as a result of the rapid increase of IoT data volume, high-speed connectivity and high-performance computing [8].
It is the AI that can augment greatly the value of IoT by making use of all the data from huge number of devices to drive to improve the ML algorithms and make machines learn.

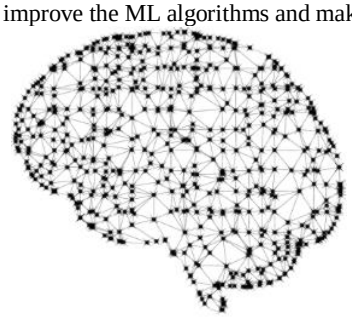

Figure 3, AI connectivity

AI in the context of 5G

In the context of 5G and the enhancement of mobile networks, AI and ML are interchangeably used, but they differ from each other. AI is a broad concept that does certain tasks in a smart way and closer to humans. It
relies on ML to collect the data and analyse the pattern from which the software system learns and improves and this makes machines smarter. On the other side, ML is a subset of AI and is seen as an application of AI to allow machines access to data and learn for themselves. ML is also known as a current-state-of-the-art of AI.

When it comes to the use of AI/ML in 5G and whether this can help 5G to handle its complexity, there are two approaches:

- Basic approach where AI/ML is used to perform some basic tasks based on some pre-set algorithms
- More advanced approach where AI/ML is used to be more context aware and learn from the surrounding situations and acts accordingly
    - This approach has emerged with the popularity of Internet and the huge amount of the generated information
    - Instead of teaching the computer to do everything, it is better to code them to think like humans and give them access to the huge information enabled by Internet and 5G

Internet of Things (IoT)

Is a system of devices connected together. By devices in the context of IoT is meant any device from tiny sensors to wearable and smartphones.

These devices can talk to each other and gather a lot of information that when analysed can create a lot of useful information that can be used by different entities to perform a specific task or learn from those information.
In the context of this paper, the information gathered from these IoT devices can be used by AI in order for the AI algorithm to learn.

Figure 4, IoT devices

What functions of 5G can AI help with?

Number of functionalities and services provided by 5G is so high that managing and configuring them manually may become a bottleneck and would require some form of automation. This form of automation would be difficult without AI. An example of such a functionality would be the network slicing, see figure x, as one of the main 4G and 5G functions, that currently are manually configured. Once the 5G deployment starts rolling out, the number of network slices will be much higher and manual configuration would affect operator's abilities to provide this service. Use of AI in this case would simplify the configuration drastically by filtering and routing backend traffic based on device needs and as such enhance operator's abilities to provide this service.
Another case where AI could be leveraged is to enhance device abilities through a better understanding of their surroundings, i.e. to improve contextual awareness. The improvement of contextual awareness can only be achieved with 5G as a technology with a very low latency.
Other case where AI and ML can help the 5G is with the beam selection and steering and by identifying and computing the strongest beam or strongest set of beams, i.e. beam reference signal (BRSRP). Based on these computed beams, the serving cell site decides if the UE needs to switch and when to switch to a neighbouring cell and what specific beam to connect to.

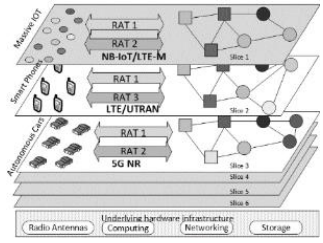

Figure 5, Network slices

The key advantages that operators gain from AI and ML for 5G enables are as following:

- High level of automation leading to minimum or no involvement of human interaction and as such more efficient service to offer
- Traffic aggregation and traffic steering from different access networks through different applications
- Capability to provision resources to different use cases, e.g. network slice, with different QoS
- requirements in a very dynamic way
- Collection of real time information and construction of a complete user profile including user subscription, QoS requirement, network performance and other events and logs

Intelligent Connectivity

Is a new concept built on a fusion of three major technologies, 5G, IoT, which is meant to serve as a means to accelerate the development of disruptive digital services.
This new concept facilitates connection of devices through a fast and low latency mobile network, that is 5G, collects digital information through the machines and sensors, which is the function of IoT then analyses and contextualizes by AI/ML and finally generates meaningful outcome useful for the users. This would enable new transformational capabilities in most of the industry sectors, e.g. transport, manufacturing, healthcare, public safety, security etc.

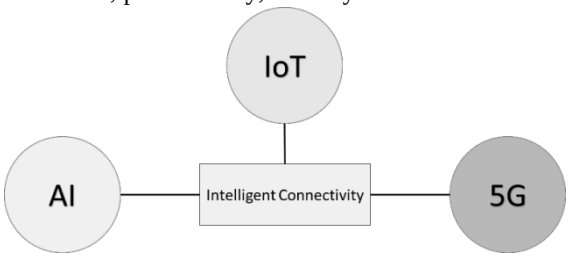

Figure 6, Intelligent connectivity

Areas of applications of AI in 5G

The number of areas in mobile networks and in 5G specifically where AI could apply is huge, but some of the main areas where AI could be used are [5]:
Network planning-where operators will use AI to improve the network capacity planning which will lead to cost reduction and better performance of the network.
AI and machine learning methods can be applied to predict and forecast the traffic by detecting traffic patterns and as such learning online and helping with the automation of decisions. This avoids the need for over- provision as it is the case with the traditional network capacity planning.
Management of network performance- allows a network controller to learn from experience while it enhances the network.

Management of customer experience- AI will help to improve and manage the customer experience by using the IoT data that reveal important consumer insights in the context of real-time situations. This helps the consumers and provides them with an experience tailor-made to their life.
Management of product life cycle- Artificial intelligence helps to manage and improve the product lifecycle by leveraging the data that describe the current and historical product insights, root causes and correlations, future outcomes and recommended improvements. This helps to transform the product lifecycle from a data management tool to an intelligent decision-making system.
Management of network itself – Artificial intelligence and machine learning can help the software-defined networks to learn how to manage themselves by using operational data. This requires some training of the network to manage itself for some initial and simple operations. Initial application of AI to network operations includes some security functions, such as security attack mitigation, automated path selection, and some basic operations running on 'auto-pilot'.
Management of revenue – Adoption of AI in 5G is already happening and will reduce the capital expenditure and as such improve the revenue stream.

Conclusion

This paper highlighted the key features and benefits of using AI/ML in 5G and how can 5G also impact the AI development by facilitating the access to relevant data. The paper also highlighted that areas with the greatest benefit from AI in mobile communications are the management of cost and network efficiencies and the improvements to customer experience.
However, to make a full use of AI/ML in 5G, the development of standardised interfaces to enable access to relevant data is needed, and this is anticipated to be the main challenge. Another challenge is to explore and examine the use of AI for customer experience optimization and to automate network operations including network planning and network management.
Some of the key points of this paper are that AI is being deployed in networks, will be critical for customer service and will help the network operates to regain the investment.
As for the future work in this field, all the interested stakeholders, such as industry, academia and research, should increase the efforts to transfer the intelligence on the end devices and end things that would make them smart things as opposed to only access the relevant data and make the network smart.

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