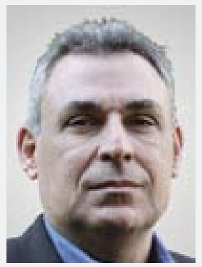
Yang Jin



Miguel Dajer

Artificial Intelligence and Machine Learning will abstract data to make next-generation communication breakthroughs come to life. >>

AI-enabled Mobile Networks

| By Yang Jin, Director, Network Data Analytics Research, and Miguel Dajer, Vice President, Wireless Access Department, Huawei Technologies Co., Ltd.

Breakthroughs in Artificial Intelligence (AI) and Machine Learning (ML), including deep neural networks and probability models, are creating paths for computing technology to perform tasks that once seemed out of reach. Taken for granted today, speech recognition and instant translation once appeared intractable, and the board game 'Go' had long been regarded as an edge case for the limits of AI. With the recent win of Google's 'AlphaGo' machine over world champion Lee Sedol — a solution considered by some experts to be at least a decade further away — was achieved using a ML-based process trained both from human and computer play. Self-driving cars are another example of a domain long considered unrealistic even just a few years ago — and now this technology is among the most active in terms of investment and expected success. Each of these advances is a demonstration of the coming wave of as-yet-unrealized capabilities. As one of the world's largest manufacturers in the communications technology industry, Huawei is obliged to explore the implications and opportunities that these AI breakthroughs offer across our lines of business.

The wireless communications system is one of the most complex inventions in history yet has had a deep and impactful effect on the daily lives of users around our planet. We who are scientists and engineers in the telecommunications industry are continuously planning new features to enhance the performance and capacity of the global network, including the tools and services necessary for operators to manage and optimize their technical facilities. Huawei has been especially successful in meeting customer needs and delivering high-value, low-cost products. As referenced above, recent developments in AI foretell many new opportunities for improving the operating performance of wireless networks.

Why AI?

With over 30 years of commercial history and many more needed to understand information theory, the wireless communications industry is unquestionably a mature business. And yet, unrealized capabilities encourage our imaginations. By what means and in what territories are we most likely to find the breakthroughs needed to realize these next levels of expression? AI is a candidate platform for the kinds of innovations that are attractive for designing new products for use in large-scale commercial networks.

The fundamental changes driving the incorporation of AI into wireless communications systems include:

● Intelligent Decision Making to Manage Complicated Resources and Dynamic Traffic

In early voice-centric networks, the basic resource structure unit was the time slot; the model was very predictable radio traffic. The complexity needed to manage traffic demand was quite low relative to today's standards.

Smartphone usage has significantly changed this profile, since radio traffic models today necessarily include multiple dimensions and granularities. First, networks are increasingly heterogeneous, and user devices are often equipped to be served by one or more technologies — such as 2G, 3G, 4G, Wi-Fi, et cetera. Within each technical domain, operators have the option to combine multiple layers of cells, and various radio beams can be organized to better serve expected use patterns. Additionally, cells can be turned on or off dynamically to manage loading or interference or to save power.

There are large numbers of application types that affect the characteristics and interactions of user traffic in unique ways and, therefore, require a range of specific treatments. Given even this very brief description, it is possible to see the magnitude of complexity required by policy control systems to apply multi-variant decision trees at different operational levels. These decision trees ensure optimal user experiences under diverse traffic demands and radio conditions. The coming era of 5G communications will further increase the number of use cases that must be managed. In the example of Network Functions Virtualization (NFV), computational resources will be dynamically assigned with the goal of having core decision-making algorithms automatically adapt to current radio, user, and traffic conditions. We believe that ML and other AI technologies are the best candidates to enhance the capabilities of complex decision making for advanced wireless systems.

● Automation to Improve Efficiency and Reduce Cost

Operating increasingly complicated networks efficiently and at a low cost is a challenge for operators. Many of them must manage at least two to three networks while maintaining, or even reducing, the cost of operation with limited, basic toolsets. The situation was feasible for the voice-centric network of the past but not for today, as network behavior and performance factors are much more dynamic and unpredictable. For example, spikes in social media activity that affect network behavior can strike at any time. Additionally, user experiences are becoming the focus of network operation and optimization, rather than network performance. Traditional methodologies and toolsets lag behind the times, and changes in technology are required to support different network use models.

AI is a candidate platform for the kinds of innovation that are attractive for designing new products for use in large-scale commercial networks. >>

● Digital Transformation and On-demand Service Provisioning

Operators worldwide are transforming their networks to increase their use and the number of services they can transport. As a result, carrier networks are evolving closer to typical data center cloud service offerings in the way they are used, provisioned, and orchestrated. Today's focus is on leveraging cloud technologies and network virtualization to offer these services, while reducing capital and operating expenditures and achieving significant levels of automation. Data analytics-enabled capabilities will provide superior End-to-End (E2E) system visibility, quantification of resources and performance modeling, automated system monitoring, and self-corrective, proactive actions. These tasks are critical to the future success of the wireless industry.

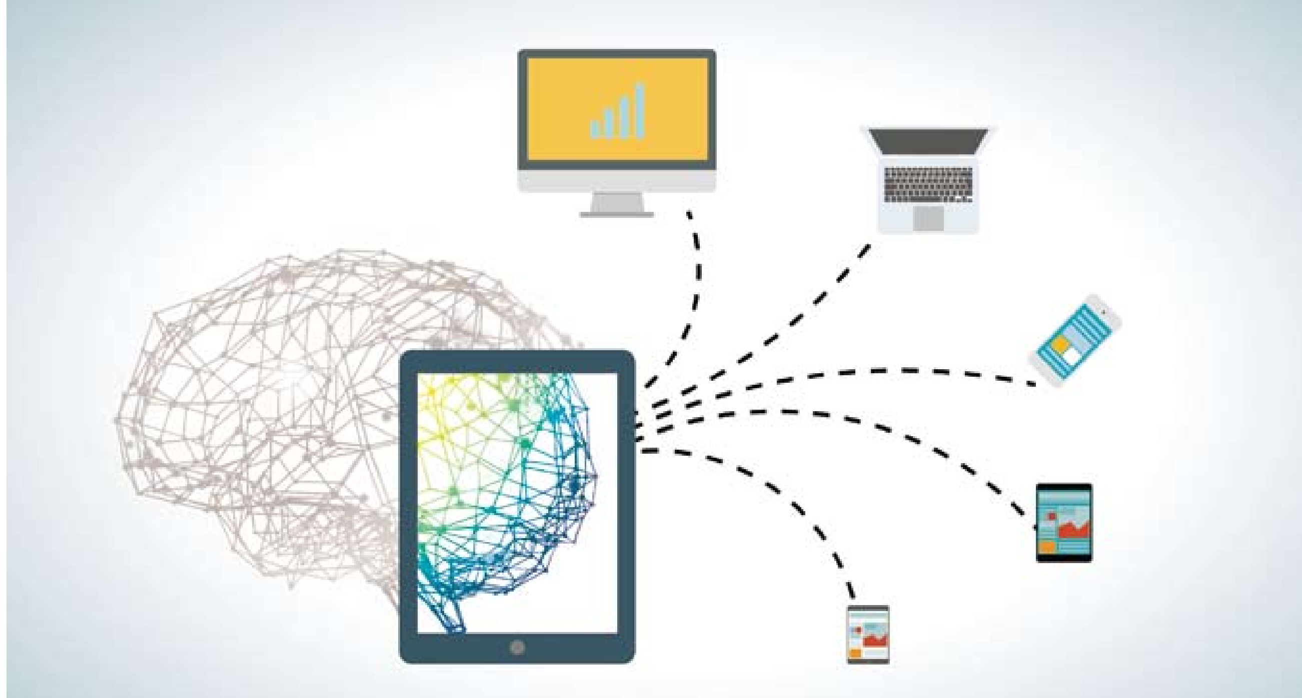
How will AI Help?

● Data Analytics and Machine Learning

Data analytics is the science of collecting, organizing, and analyzing large data sets to identify patterns and draw conclusions. There are four types of analytics that can be applied for wireless pipe design, operation, and optimization:

- **Descriptive Analytics** examines and analyzes past performance by mining historical data to discover the reasons behind past successes and failures. Management reports such as sales, marketing, operations, and finance use this type of post-mortem analysis.
- **Diagnostic Analytics** focuses on determining what factors and events contributed to and explain the outcome. It is all about making 'why' statements.

We believe ML has the potential for a broad range of applications that can improve cellular network design, operation, and optimization. >>



• **Predictive Analytics** turns data into actionable information. Predictive analytics use data to determine the probable future outcomes or the likelihood of any particular event to occur. Predictive analytics employs statistical techniques that include ML, modeling, data mining, and game theory to assess current and historical facts to predict future events.

• **Prescriptive Analytics** automatically synthesizes Big Data, business rules, and ML to suggest decision/action options to take advantage of the predictions. Prescriptive analytics continually and automatically processes new data to improve prediction accuracy and provide better decision options.

ML techniques and statistical models support the different types of analytics mentioned above. ML and all its siblings comprise a key foundational technology for many advanced algorithms used in wireless communications, from optimization to OSI Layer 1 processing. Extracting hidden information from vast amounts of data created by wireless communications algorithms is the challenge that U.S. companies are undertaking as part of their wireless research and development efforts. We believe that success in this space will yield significant advantages to our products.

Deep Learning (DL) — known as deep structured learning, hierarchical learning, and deep machine learning — is a branch of ML based on algorithms that model high-level data abstractions using multiple processing layers, complex structures, and/or non-linear transformations. Much of the research in this area attempts to make better representations and create models to learn these representations from large-scale, unlabeled data. Some of the representations are inspired by advances in neuroscience and are loosely based on the interpretation of information processing and communication patterns in a nervous system, such as neural coding that attempts to define a relationship between various stimuli and associated neuronal responses in the brain.

Today, DL has almost taken on a life of its own. Google's DeepMind DL platform beat a 9-dan master in the game of Go. The system utilized DL along with reinforced learning as its core technology. Investments in ML, and especially DL, are growing rapidly, and companies like Google have begun to 'open source' their DL platforms to encourage innovation.

● Machine Learning-enabled Wireless Pipe Design, Operation, and Optimization

We believe ML has the potential for a broad range of applications that can improve cellular network design, operation, and optimization. The following scenarios illustrate the potential power of ML and related technologies:

• **Self-Learning and Adaptive Networks:** A fundamental challenge in wireless system design is to manage and allocate resources to meet traffic demands under difficult constraints. Problems traditionally are resolved by applying sets of rules derived from system analysis and simulation with prior domain knowledge and experience. The level of intelligence is determined in the design phase, and the system behaves according to pre-programmed rules. However, this method faces increasing challenges due to today's dynamic and diverse traffic, and the complexity of network architectures and resource structures. Our vision is that future networks will be self-learning and adaptive to the needs of its user devices, radio conditions, and characteristics of application-based traffic. Decision quality will continue to grow by learning from past behaviors and outputs, and also from similar entities in the same or other networks.

• **Proactive Network Monitoring and Root Cause Analysis:** Network monitoring and maintenance are critical tasks in network operations. Today, we rely on alarms for monitoring; however, static alarm thresholds at the cell level lead to many missed alarms due to the dynamic nature of the cellular environment. For root cause analysis, we rely on knowledge-based engineering troubleshooting guides, although there are clear limitations to this approach. First, because engineers often propose one-size-fits-all guidelines, the rules may be inaccurate or need to be adapted to a different market. This clearly is no longer acceptable. Second, and more importantly, these troubleshooting guidelines are limited by engineering knowledge and are useful only for 'known' issues. But what of new and unexpected troubles? It is common knowledge that new issues occur for many reasons that require experienced engineers to investigate and formulate solutions. This can take a long time to resolve, making customers unhappy. This gap in time also can increase the cost of operation. In a world of instant gratification, this approach is insufficient. By applying diagnostic analytics, we can quickly and accurately perform root cause analysis to detect network problems and resolve them, even before they occur.

• **Automated and Closed-Loop Optimization:** Today, optimization relies on engineering knowledge and manual processing and analysis. However, the growing complexity of network technologies and cost-saving pressures call for more automated and scalable solutions. The key capabilities that allow automated and closed-loop optimization are root cause and/or specific scenario incidents that trigger optimization engines or agents. The engine or agent combines domain knowledge and data-driven search settings.

• **User Experience-Driven Network Planning:** Network planning is the first and most critical step for any network rollout. The quality of planning determines, to a large extent, user experiences and Return On Investment (ROI). Traditional network planning tools focus on the coverage capacity for voice services that is relatively simple to predict. Today, data traffic (including video) dominates the cellular traffic mix, while user experiences depend heavily on optimized parameters like data throughput and delay. ML and predictive modeling enhance network planning tools so that the network is more likely to meet not only the coverage target but also the user experience requirements of all customers.

• **Active Security Protection:** The ICT industry is facing an ever-increasing number of security incidents; this, in turn, drives substantial business issues, including outages and loss of revenue and credibility. We believe that ML is essential for strong security defenses at different layers of the network. Behavioral analytics that leverage ML make a difference in detecting attacks, automatically analyzing varied data from multiple perspectives, and identifying the relationships between disparate actions.

In the past, we carried out a series of projects to explore ML technologies and their applications for pipe design and operation. For example, cell-level anomaly detection and root-cause analysis have been tested in real network environments and have gained very positive feedback from operators. Our self-learning/adjusting solution for coverage and capacity optimization is now part of Huawei's Self-Organizing Network (SON) solution. We are continuing the journey by exploring the latest advances in AI and ML, especially in the areas of deep and reinforcement learning. We believe this will enhance our capability to capture and abstract underlying data structures to achieve further benefits from the large amount of data that networks generate.

Business Roadmap

Wireless communication systems are greatly transformative. Therefore, the underlying technology must evolve to support larger demands beyond personal communication and into the Internet of Things (IoT). Service providers are exploring new business models to continue to increase business opportunities and drive toward further successes. AI technology plays an important role in this journey by enabling intelligent decision making at the core of system design, automated operation, and optimization. These key elements provide the necessary insights for new business models. ▲

New ICT

Service providers are exploring new business models to continue to increase business opportunities and drive toward further successes. AI technology plays an important role. >>