

AT&T'S LEGACY OF INNOVATION

THE DISRUPTIVE POTENTIAL OF 5G, EDGE AND SOFTWARE DEFINED NETWORKING

EXECUTIVE SUMMARY

The deployment of 5G will revolutionize fixed and mobile services with its ultra-low latency, blazing-fast throughput, and ability to support a massive number of connected devices. In addition to greater speed and responsiveness, 5G will redefine connectivity and the subscriber experience by enabling a new era of network-based intelligence, virtualization, and computational power at the network edge. Tactile applications that require instantaneous response and precise control — such as mobile gaming, mixed reality, smart factories and cities, telesurgery, and autonomous driving — will benefit and come to fruition. As 5G networks are deployed globally, many carriers are still focused on access. However, some providers, such as AT&T, stand out for their efforts toward enabling compelling use cases.

Despite the excitement and focus on 5G, 4G LTE will continue to be an important modality within cellular networking. 4G is not only democratizing mobile data access at the consumer level; it also supports needed network densification, consumer services such as content streaming and ride sharing, and enterprise applications such as private networking. As these demands grow, 5G will provide the needed headroom for existing applications and services, as well as a host of new ones.

5G also brings new software-defined networking (SDN) capabilities that optimize service performance through network slicing, enhanced network functions virtualization (NFV), white box hardware, open source, and mobile edge computing (MEC). As a result, carriers will gain operational expense (OpEx) and capital expense (CapEx) relief and will realize improved reliability and performance capabilities in the face of rising service demand. Additionally, they will be better positioned to compete with Over-The-Top (OTT) application providers to take advantage of new monetization opportunities.

To claim leadership, carriers must accomplish a number of things:

- Virtualize and edge-enable their 5G access network by placing compute resources closer to users and data creation points

- Deploy SDN, Internet of Things (IoT) platforms, devices, and sensors, artificial intelligence (AI), and open source software resources at the core
- Ensure subscriber privacy and security

This effort requires an extraordinary number of resources, knowledge, and core competencies. Moor Insights & Strategy believes that AT&T is uniquely positioned to capitalize and bring compelling 5G use cases and services to market while advancing networks beyond simple access. AT&T has the capabilities to drive 5G innovations given its rich legacy of innovation, deep collaborations with infrastructure providers, and leadership in consortia and shaping 5G standards, as well as its significant global investments in the AT&T Labs and AT&T Foundry initiatives.

PROVEN INNOVATION, LEADERSHIP, AND ECOSYSTEM DEVELOPMENT

AT&T has a storied past. Founded nearly 150 years ago, the communications giant can lay claim to one of the most significant inventions ever to advance human communications: the telephone. According to AT&T, it is the recipient of eight Nobel Prizes and, with thousands of engineers around the globe, is issued five new patents daily.

SOFTWARE-CENTRIC NETWORKING INNOVATION

While AT&T is best known for its iconic hardware inventions, most of its innovative research today is actually software-based. The company, which is transitioning to a software-centric network that delivers new services with greater speed and agility, claims to have contributed more than ten million lines of code to open source projects in recent years.

Furthermore, AT&T participates and leads multiple open source software groups and forums — such as the Linux Foundation, O-RAN Alliance, and OpenStack — and has released several co-development platforms into the open source community. These include the network-orchestration platform Enhanced Control, Orchestration, Management, and Policy (ECOMP) (available as Open Networking Automation Platform or ONAP), Acumos (an AI developer marketplace), Akraino edge stack, and Airship, the foundation for AT&T's 5G Network Cloud. From our perspective, all of these efforts clearly demonstrate AT&T's innovation and market leadership.

LEADERSHIP IN 5G STANDARDS

AT&T contributed significantly to the shaping of the 5G standard itself. The company claims to have made over 500 contributions through the Third Generation Partnership Project (3GPP) that encompasses 36 patents. Two specific examples of AT&T's contributions to 5G standards include [Dynamic Spectrum Sharing](#) (DSS) and Integrated Access and Backhaul (IAB).

DSS is a significant innovation, given 5G New Radio (NR) will be introduced on both new and legacy sub-6 GHz spectrum bands. Until new spectrum is available to dedicate to NR, operators must deploy 5G sub-6 in bands currently used for 4G LTE. In the past, the change from one "G" standard to the next involved "re-farming" spectrum, which resulted in inefficiencies and negative performance impacts. In an effort to move beyond legacy bottlenecks, AT&T co-developed the concept of DSS with Qualcomm and other industry leaders to allow both modalities to operate concurrently and dynamically using the same spectrum resources. We believe that DSS is a "game changer" and will accelerate 5G deployments faster than any previous generation of cellular networking topology.

Operators face two key challenges as they move to the deployment of millimeter wave (mmWave) spectrum to support 5G services: the required density of small cells to extend signal propagation and the need for robust transport. Both are expensive and time-consuming to deploy, and in some circumstances laying new fiber is not economically or physically feasible. To solve these challenges, AT&T developed the concept of IAB, included in Release 16 of the 3GPP 5G NR standard. IAB facilitates the deployment of small cells with significantly reduced fiber-transport requirements. Instead of using fiber as the backhaul at every site, IAB cells use the same air interface and antennas for both user equipment (UE) access and to backhaul the data. This creates a multi-hop relay network between sites — without the need for incremental equipment or antennas — that drives significant efficiencies. We believe that IAB has the potential to dramatically reduce operator CapEx, freeing financial resources for more value-added activities such as the development of new subscriber services.

ECOSYSTEM DEVELOPMENT

Building ecosystems is also key to success in the telecommunications industry. To that end, the company established the AT&T 5G Innovation Program in 2019. The program builds on the 5G innovations of AT&T Labs and AT&T Foundry. Besides AT&T, the consortium includes enterprise and cellular infrastructure stalwarts including Cisco,

Ericsson, and Nokia. The mission of the program is to facilitate application development with infrastructure providers and device developers, as well as content creators such as WarnerMedia. Consumer, enterprise, and public sector use cases based on 4G LTE and eventually 5G include education, entertainment, gaming, retail, sports, and more. From a consumer services perspective, AT&T's content from its acquisition of Time Warner in 2018 uniquely distinguishes it from competitors in the United States. However, building compelling 5G services for consumer and enterprise applications also requires a significant investment beyond content and infrastructure initiatives. We believe that AT&T is a leader in this regard with its Labs and Foundry efforts.

AT&T LABS

Founded nearly 25 years ago as a direct descendent of the original Bell Labs, AT&T Labs operates from several locations across the United States and abroad and employs thousands of engineers, developers, scientists, and more. From a mission perspective, the organization focuses on three core technology pillars: 5G, SDN, and AI and machine learning (ML).

- With respect to 5G, the research effort explores virtualization and cloud native platforms to enable scale and deliver a truly distributed network through NFV and network slicing. AT&T Labs also leads new device and deployment testing for 5G; drives the standards and open source communities in 5G and cloud; and provides all of the access capabilities that AT&T deploys in the field for its many subscribers.
- From an SDN perspective, we believe AT&T is driving carrier-grade network transformation at scale through innovation in hardware and software disaggregation. This includes the deployment of white box platforms, cloud-enabled network function virtualization (NFV), and open source adoption and contribution – with an end goal of delivering a network that's more responsive, upgradeable, and secure from core to edge. As a proof point, AT&T is well on its way to virtualizing the majority of network functions by the end of 2020. During this journey, the company has elevated the adoption of developer operations (DevOps) automation, embarked on one of the largest OpenStack-based cloud infrastructure deployments globally, and strengthened industry capabilities by open sourcing its Enhanced Control, Orchestration, Management, and Policy (ECOMP) platform that has the potential to deliver improved agility and lower operator OpEx.

- With respect to AI and ML, it's all about the data! Given the dramatic proliferation of data, the AT&T Labs team is leveraging deep learning and analytical models to research and deploy new ways to process data sets and draw meaningful insights. These capabilities not only improve network planning, but also deliver internal efficiencies and reduce costs. The algorithms applied to this effort are only as effective as the data lake used to train them, thus we believe that AT&T's significant customer base provides an advantage over its rivals.

AT&T Labs operates across several locations, but from our perspective three are worth noting, given their significant contributions to AT&T 5G innovation: Redmond, Washington, Austin, Texas, and Tel Aviv, Israel. AT&T's Redmond scientists helped AT&T launch one of the first fully software-based 5G cores, which manage network operations with unparalleled flexibility and agility. AT&T's Austin engineers launched the industry's first 5G business-customer trial in the United States by successfully showcasing high-quality video streaming and conferencing using mmWave spectrum. The Austin team also collaborated with National Instruments in early 2017 to develop innovative mmWave-based technologies to measure and deliver 5G signals. This resulted in what AT&T claims is the world's first-ever mobile 5G field connection. Austin will also play a strategic role in evaluating the vehicle to vehicle (V2X) platforms that will enable self-driving cars in the near future. This 5G use case is one of the most compelling and transformative, touching both the consumer and the enterprise.

In Tel Aviv, the AT&T Labs team focuses on improving customer experience through network automation aimed at achieving cost efficiencies and new revenue opportunities. Two specific examples of their efforts that we find compelling are AT&T DataFlow and Xandr.

- DataFlow is a cloud-agnostic data platform that massively scales to facilitate building custom solutions from “sandbox to full deployment.” Its use cases include:
 - Fleet management
 - Asset management and tracking (such as connected coolers for smart replenishment, or wheelchair tracking in primary and secondary care facilities)
 - Smart cities (such as optimization of HVAC systems, water tank monitoring, and oil & gas applications)
- The AT&T business unit Xandr uses an advertising analytics platform that adds value by improving consumer impact. The Israel Labs team is working with Xandr

across three areas of focus: ensuring advertising does not obstruct content; making advertising more relevant; and creating fun, engaging interactions with viewers.

AT&T FOUNDRY

While AT&T Labs is focused on the technology, architecture, and development of the network, AT&T Foundry's mission is to collaborate with customers and innovators to build enterprise solutions prototypes. Dating back nearly a decade, the Foundry operates six sites around the world and meets with over 400 startups annually to identify the best candidates for collaborative innovation. Each location is co-sponsored by infrastructure leaders such as Ericsson, Nokia, and Amdocs. The Foundry is focused on developing 5G and edge use cases. These include network edge computing (NEC) and MEC, with each location bringing additional specialization in areas such as:

- Connected healthcare
- Network virtualization
- Gaming
- Artificial reality (AR), virtual reality (VR), and mixed reality (XR) applications
- Industrial use cases
- Small and medium business process optimization
- Startup incubation

Moor Insights & Strategy has visited several Foundry locations around the world, including Palo Alto, California; Plano, Texas; and Ra'anana, Israel. The AT&T Foundry in Palo Alto recently reimagined the VR delivery pipeline to improve low latency access via edge cloud computing. As a result, they have successfully demonstrated the industry's first PC-quality, untethered VR experience running solely over a 5G wireless connection. AT&T accomplished this in collaboration with a diverse ecosystem of partners to create a technology stack that included 5G edge, head-mounted displays (HMD), cloud VR, network, and content integration.

In Plano, the Foundry team helps businesses solve process challenges through 5G, edge, and IoT platforms. One of the more interesting business cases demonstrates how AR worker-assistance solutions become truly viable with 5G edge. The demo, an immersive and interactive XR training module, helps users perform maintenance on aviation equipment. It demonstrates how MEC, NEC, network slicing, and 5G can combine seamlessly to deliver an extremely compelling end-to-end customer experience.

Moor Insights & Strategy witnessed more innovative use cases on a visit to Ra'anana, Israel, in late 2019. From our perspective, the Ra'anana Foundry team's work on 5G, MEC, cybersecurity, and network operations is trailblazing. The catalyst is a vibrant start-up community, for which AT&T provides a 5G and edge-computing test bed for design and prototyping. AT&T also provides mentorship to facilitate business process and acumen development, as well as cross-collaboration with industry and government organizations. The Israeli government makes significant investments in technologies that are born out of its citizens' compulsory military service, which contributes to the uniquely innovative environment. The success of AT&T's investment in the region is evidenced in three innovative startups: Nexar, NoTraffic, and Vorpai.

- Nexar and NoTraffic have created a connected vehicle-to-vehicle network solution that uses low-latency edge computing to aggregate, analyze, and deliver traffic data to cities, transit authorities, and mobility and mapping companies. This data is used to make roads safer and more efficient for drivers.
- Vorpai successfully tested edge computing methods to detect, geolocate, and monitor drones in real time — in both rural areas and dense urban environments — to support security and counter-drone intelligence operations.

ENTERPRISE AND CONSUMER PROOF POINTS

Proof of use-case viability is in the deployment, and AT&T is pursuing a range of enterprise, governmental, and consumer 5G applications.

- Moor Insights & Strategy visited the AT&T Samsung Semiconductor Innovation Zone in Austin, Texas, in January 2020. Enterprise use cases being explored by Samsung in conjunction with the Plano Foundry, in our opinion, have the potential to revolutionize manufacturing operations globally. Leveraging 5G connectivity and its ultra-low latency, low-power, massive device support, and network slicing capabilities for IoT sensing and smart camera deployment will bring dramatic improvements in worker safety and production yields. Like most manufacturing facilities, Samsung Austin Semiconductor collects data from thousands of machines. 5G can enable manufacturers to enhance the scale and volume of data collection, improve process flexibility by eliminating wires, and maximize the ability to process data in near real time. In addition to improving efficiencies, the increased bandwidth and reduced latency delivered by 5G can be used for predictive maintenance of mission critical machinery. 5G's lower

latency could also enable critical data to be transmitted to first responders without delay in the event of a plant emergency.

- For governmental use cases, AT&T recently announced that it will provide 5G services including FirstNet, the nationwide public safety communications platform, to Nellis Air Force Base in Southern Nevada. The most significant 5G use case at Nellis beyond FirstNet includes support for flight communications and operations. 5G can enable mission data-transfer rates at higher speeds with lower latency between a host of data platforms, sensors, aircraft to on-ground personnel, video surveillance, and analytics. We believe the result could be improved security and safety and richer, more immersive training opportunities. To learn more visit: https://about.att.com/story/2020/nellis_airforce_base_5g.html
- For consumer use cases, we believe AT&T Stadium and the Dallas Cowboys experience is a compelling example of the power of 5G. 5G and AR have come together in what AT&T claims to be the first 5G enabled stadium, which offers four different user experiences, live player statistics, and team performance updates in real time. To learn more visit: https://about.att.com/story/2019/5g_at_att_stadium.html

CALL TO ACTION

The deployment of next generation 5G networks will revolutionize fixed and mobile services. Carriers that focus on use case versus access will reap the rewards in the form of lower subscriber churn, higher loyalty, incremental revenue, and higher profitability.

Demand for mobile data will also continue to grow and place immense pressure on cellular networks. It is therefore incumbent that SDN, NFV, NEC, MEC, automation, and open source be deployed to ensure scalability and operator agility. Not all carriers have the knowledge, resources, or acumen to implement these software-defined platforms.

Moor Insights & Strategy believes that AT&T is well-positioned to capitalize and bring compelling 5G use cases and services to market. This is demonstrated by AT&T's:

- Legacy of innovation marked by significant accomplishments in SDN, AI, and ML realized through the AT&T Labs organization

- Discrete focus on 5G and edge use cases and applications born out of the AT&T Foundries
- Leadership in helping to shape the 5G NR 3GPP standard
- Open source networking leadership

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