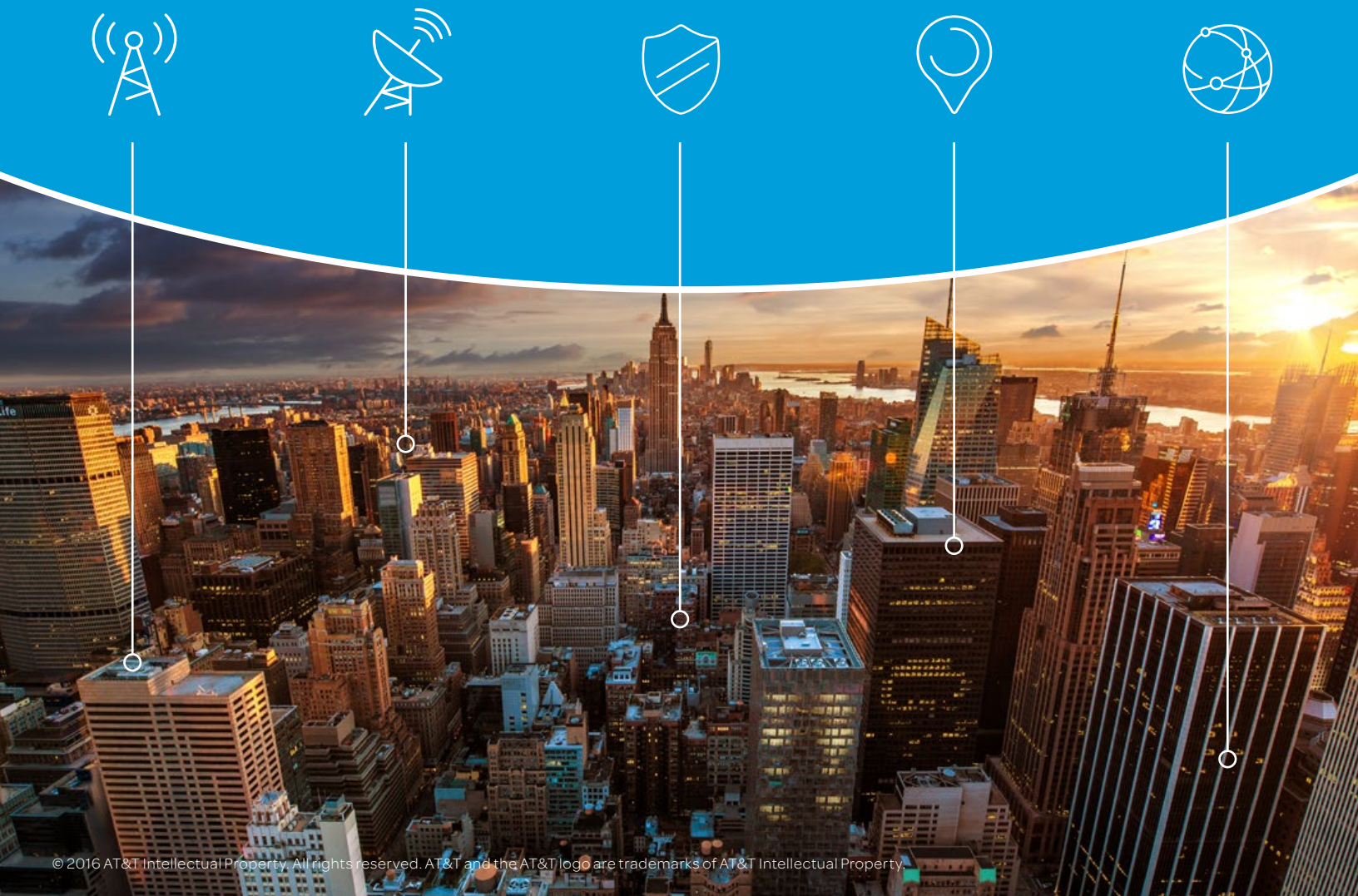
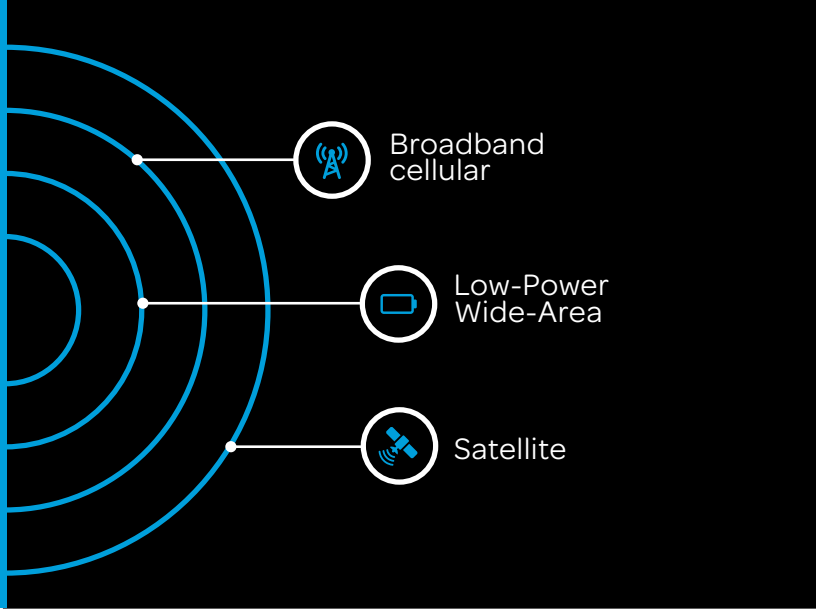
MOBILIZING YOUR WORLD

What you need to know about IoT wide area networks

How to choose the right WAN technology for the Internet of Things



IoT networks are evolving



Choosing the best wireless technology for your Internet of Things (IoT) takes careful consideration. In this whitepaper, we examine IoT wide area networks (WANs) including cellular, Low-Power Wide-Area (LPWA), and satellite services to help you choose the right network technology for your specific needs.

IoT wireless networks are evolving to help meet the needs of a wide variety of connected devices—from wearables, cars, and homes to streetlights, parking meters, and industrial automation devices—so they can work seamlessly together. With such a broad diversity of potential applications, it can be difficult, if not impossible, to bring a one-size-fits-all approach to every situation.

To choose the right network requires consideration of many factors: from coverage needs and device location to power consumption and the cost of deployment. Each of these factors can contribute to a different network decision.

Broadband cellular connectivity has dominated the IoT landscape for more than a decade. Key advantages include global reach, scalability, diversity, and high bandwidth capabilities.

When cellular is not an option, satellite services can help provide connectivity to virtually anywhere on earth. Yet, in IoT, not all connected devices require such robust capabilities.

New Low-Power Wide-Area (LPWA) networks are entering the IoT space as alternative wide area network technologies to short-range networks like Wi-Fi. LPWA technologies provide strong benefits including opportunities to help lower the total cost of ownership plus providing extended coverage and longer battery life.

As a leading integrated and global IoT service provider, AT&T understands that your IoT solutions can span across different network technologies. We offer a multi-network approach so that we can provide the flexibility and agility you need to help optimize your IoT solution.

Broadband Cellular

3G and 4G LTE

Today, several generations of cellular technology support IoT services. 3G and 4G stand for third and fourth generation technologies. LTE (Long Term Evolution) is a standard which has focused so far on broadband, high-speed wireless communications.

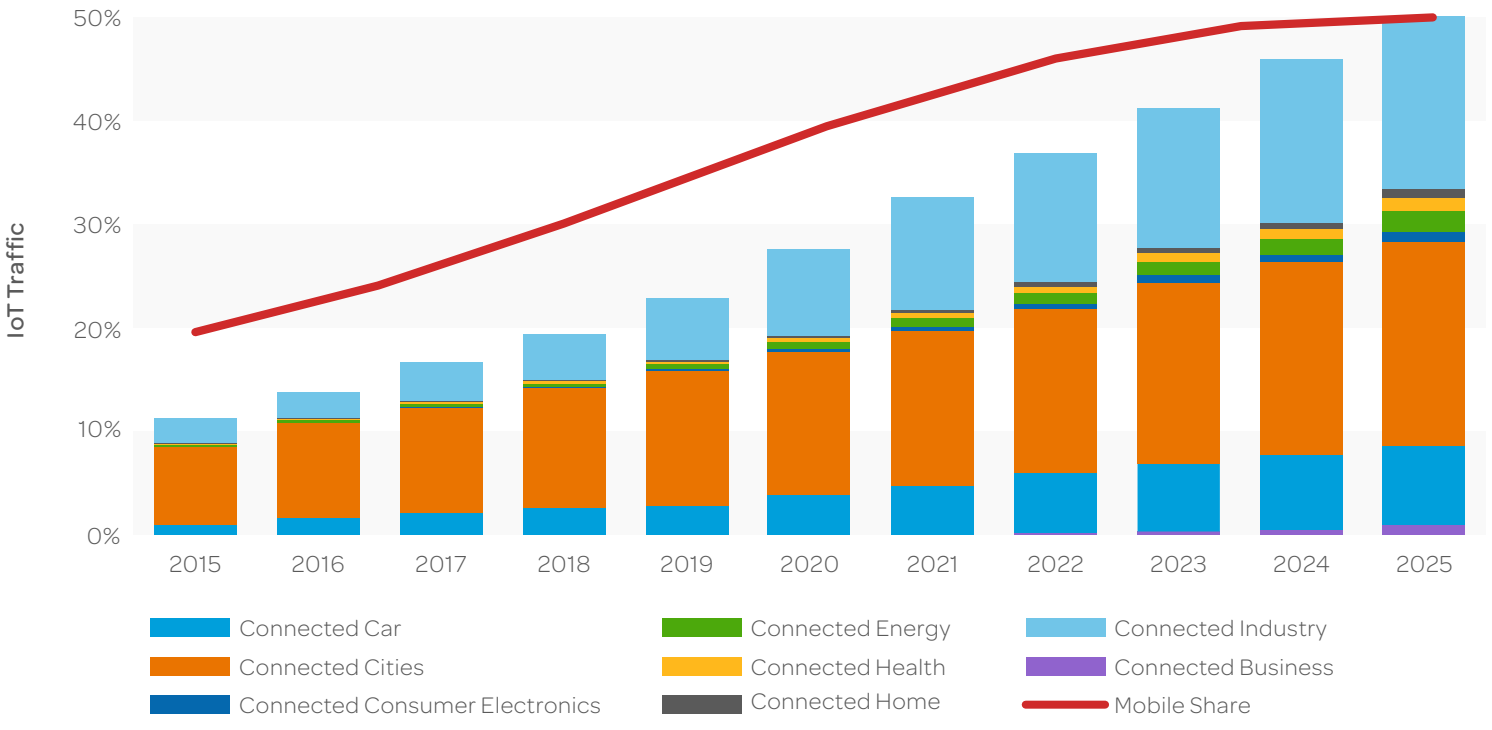
Broadband cellular connectivity has played a pivotal role in the explosion of IoT connected devices, and supports a full range of IoT applications from low bandwidth exception-based reporting to applications that have high bandwidth needs. By 2025, Machina Research expects that mobile networks will carry 50% of IoT data traffic[1].

Over the last decade, AT&T has connected more than 29 million IoT devices to its network[2].

[1] Source: IoT Global Forecast & Analysis 2015-2025, Machina Research, August 2016. Excludes consumer audio-visual applications

[2] As of Q2 2016

IoT Traffic by Sector 2015-2025[3]



[3] Source: IoT Global Forecast & Analysis 2015-2025, Machina Research, August 2016. Excludes consumer audio-visual applications

Global coverage

Cellular connectivity has long been the choice for large-scale device deployments in part due to its global coverage by Mobile Network Operators (MNOs), based on widely adopted standards. AT&T provides global coverage across more than 200 countries and territories and over 500 wireless networks with Global SIM technology. LTE coverage is currently available in 85 countries and growing.

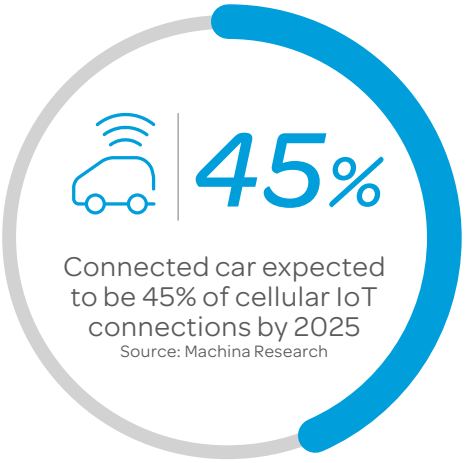
AT&T provides cellular IoT coverage in more than 200 countries and territories with Global SIM

Scalability and Performance

The scalability of the cellular network makes it well-suited for a large number of devices in a single deployment for virtually any type of asset or machine. LTE, specifically, has been designed to greatly enhance capacity and operates with a more flexible architecture allowing it to process a significant amount of data traffic.

For many low and moderate bandwidth applications that have infrequent data usage, 3G has been effective. If your IoT application uses high bandwidth, such as streaming video, 4G delivers improved performance that for many consumer and some enterprise applications, is becoming the expectation. In a recent report by Machina Research, the connected car will account for 45% of cellular connections in 2025 because it needs comprehensive coverage, high-speed mobility, and high bandwidth[4].

[4]Source: Machina Research, IoT Global Forecast & Analysis 2015-2025, August 2016



Cost-effectiveness

Cost plays a role in virtually any venture, and for IoT, device and module prices are key contributors. When new network technologies enter the space, typically the components for these new networks are more costly than their predecessors. We have seen this when comparing 3G with 4G, until recently. This trend is now changing in light of newer, lower-cost 4G LTE technologies for many IoT applications. Broadband cellular modules such as those from Winstron NeWeb (WNC) announced by AT&T in Q1 2016, are priced in the range of 3G modules today and should continue to decrease in price with large scale adoption.

High Security

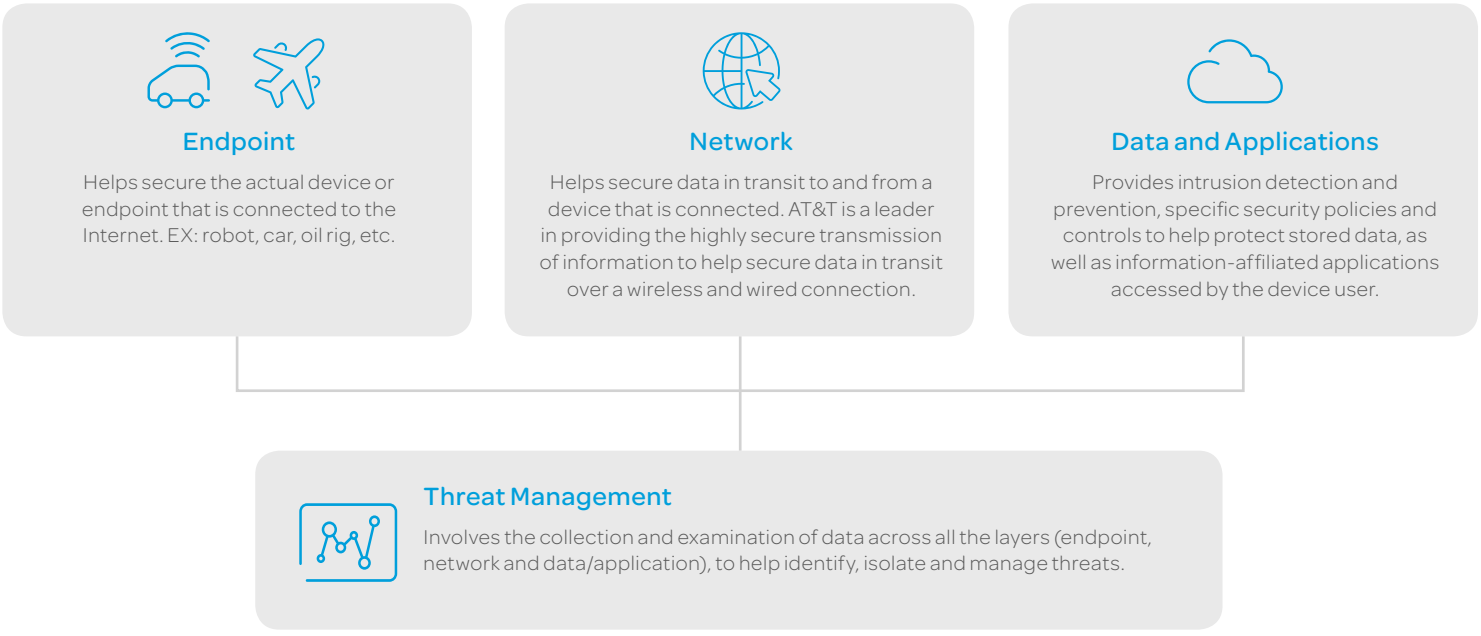
IoT solutions have many system layers and require a correspondingly layered approach to security. In addition to high security at the network layer, carrier-grade security with AT&T helps protect the device, network, and systems that make up the end-to-end solution. AT&T offers insight into IoT security in the *CEO's Guide to Securing the Internet of Things*.

5G

5G is the next generation of cellular technology and will bring about even faster data speeds and lower latency than its predecessors. Speeds could be measured in gigabits per second, rather than megabits per second. Speeds like this will likely spur further IoT innovation as well as enable improvements to solutions on the market today. That said, 5G standards may not be available before 2018, and even later for 5G-enabled IoT devices.

"Speeds could be measured in gigabits per second, rather than megabits per second"

Layers of IoT Security



Low-Power Wide-Area (LPWA)

LPWA networks are intended for IoT solutions that need low power consumption, extended battery life, and good penetration in buildings and underground. Several different technologies are being developed and deployed to support such IoT requirements. An important category of LPWA is a mobile operator-managed IoT network based on 3GPP standards for IoT networks. The two most commonly identified technologies as defined within the 3GPP standards for these purposes are LTE-M (also referred to as LTE Cat-M1) and NB-IoT (Narrow-Band IoT).

Due to its key characteristics, LPWA is likely to have a significant impact on the growth rate of future IoT innovation and spur even higher volume device deployments than are present today.

Key characteristics

Low Power

Two features defined within 3GPP standards for IoT are power saving mode (PSM) and extended discontinuous reception (eDRX). PSM and eDRX are features that enable very long battery life, with 10 years or more expected for low data usage cases. They are capable of delivering multiple years of device operation on a single, small form factor battery (assuming hourly application readings and factoring in the effects of battery self-discharge and degradation.)

Coverage Extension

LPWA is capable of today's expectations of broad cellular-level coverage, delivering nationwide and/or international coverage with specific support for urban, in-building, and subterranean environments[5]. With its coverage extension (CE) feature, LTE-M and NB-IoT devices will be able to achieve coverage in today's most challenging radio frequency (RF) environments.

LPWA can offer extended battery life of 10 years or more

[5] Source: LPWA: disruptive new networks for IoT, Machina Research, November 2015

Benefits

LTE-M and NB-IoT deliver multiple benefits that can lower the costs, and extend the range of your IoT solution. Cost and battery life have long been considered when making decisions on IoT system architectures. LTE-M and NB-IoT are uniquely suited to address both of these factors and more. A summary of benefits includes:

Longer battery life
Extended battery life of 10 years or more for enabled IoT devices.

Lower cost hardware
Chipset and module costs are expected to be in the $5 to $10 range.

Lower cost of service
Thanks to wide area coverage and the expected high endpoint capacity per cell, connectivity costs are expected to be lower than broadband cellular service.

Extended coverage
The CE feature can provide coverage up to 7X better than traditional cellular networks[6]. This includes improved connectivity within subterranean locations like basements and parking structures which makes LPWA ideal for water meters, electric meters, alarm panels, and similar installations.

7X

LPWA coverage up to 7X greater than cellular and great for basements and parking garages

[6]Coverage will vary by application and does not indicate an expanded radio frequency footprint

LPWA Technologies

There are two primary categories of LPWA technologies: licensed and unlicensed.

Licensed Spectrum LPWA

Licensed LPWA uses MNOs' current wireless spectrum holdings. MNOs have long held licenses to operate within dedicated spectrum specifically for the use of wireless communication. It is how they provide the highly reliable, scalable, and highly secure environments that large enterprises have come to expect. As described above, there are two key types of licensed LPWA technologies commonly referenced as defined within the 3GPP standards: LTE-M (Cat-M1) and Narrow-Band IoT (NB-IoT).

Unlicensed Spectrum LPWA

Unlicensed LPWA technologies use publicly available, open spectrum. Wi-Fi routers, cordless telephones, and other communication devices also access unlicensed spectrum, which can cause interference, thereby degrading performance. There are several competing LPWA solutions within unlicensed spectrum. It is unclear which of these will survive in the long run.

Licensed compared to Unlicensed LPWA

	Licensed LPWA (LTE-M, NB-IoT)	Unlicensed LPWA Technologies
3GPP standards-based	✓	✗
Dedicated licensed spectrum (Reduced Interference)	✓	✗
Carrier-grade security	✓	✗
Coverage benefits from existing cellular networks	✓	✗
Long battery life	✓	✓
Low-cost modules	✓	✓

LPWA Expectations and Predictions

LPWA networks are expected to play an important role in serving the IoT market because of lower-cost module hardware, reduced service costs, smaller form factors, improved battery life, and coverage enhancements. The question is which of the network technologies will prevail in the long run?

Dependability

LTE-M and NB-IoT operate over dedicated, licensed, and managed spectrum whereas unlicensed proprietary technologies do not. This means that there's no risk of the data traffic having to compete with non-managed devices operating within the same frequency range, as is the case in an unlicensed band. Less interference means an improved quality of service that's more dependable.

Scalability

By deploying a 3GPP standards-based technology for IoT, not only can MNOs like AT&T use their existing spectrum and avoid the potential for frequency conflict in an unlicensed range, they can also scale quickly.

LTE-M for example, can be deployed by MNOs as a software upgrade to their existing LTE network. This means it can launch quickly as a nationwide service, then scale globally over time. Standardization also leads to increased growth and adoption rates in additional ways:

- Improved economies of scale via global deployments and interoperability
- More robust solutions, since multiple companies work towards improving the end product
- Lower pricing, thanks to increased volume and scale

Security

When it comes to IoT, securing and protecting data is imperative. Because LTE-M and NB-IoT are SIM-based technologies, they deliver carrier-grade, best-in-class security measures. AT&T takes a multi-layered approach to IoT security that will also extend to LPWA. For more on the approach, read our report, *The CEO's Guide to Securing the Internet of Things*.

Technology costs

Bill of Materials (BOM) costs of LTE-M and NB-IoT modules are expected to be comparable during the first few years on the market.

Example use cases for Broadband Cellular and LPWA technologies[7]

Bandwidth	Technology	Devices
1 Gbps 100 Mbps	Cat-4	Routers • Network bridges • Gateways • High resolution video Endpoint concentrators
10 Mbps 1 Mbps	Cat-1	Video surveillance • Connected healthcare • In-car hotspot • Retail signage Digital signage • In-car infotainment • Enterprise PDA
100 Kbps	LTE-M	Asset trackers • Telematics • Smart watches • Alarm panels • Pet trackers Fitness bands • Point of Sale terminals • Gas/water meters • Patient monitors
10 Kbps 1 Kbps	NB-IoT	Smoke detectors • Parking control • Smart agriculture • Smart cities • HVAC Lighting • Electric meters • Industrial monitors

This table includes a summary of potential application use cases for cellular and LPWA IoT communication. Not all are listed and many use cases may work well across multiple network technologies.

[7]Source: CAT-M vs. NB-IoT: Energy Consumption vs. Payload, Sequans Communications, January 2016

Satellite

When IoT and satellite communications are mentioned together, maritime applications often come to mind. Whether the IoT solution is collecting data for supply chain management or shipping container asset utilization, satellite communications is the optimum, if not only, choice for monitoring devices on the open seas. Thinking beyond that, satellite networks also can be categorized as providing coverage into some of the most remote locations where customers have critical infrastructure and equipment.

There are two primary types of satellite connected devices: satellite-only, and dual-mode cellular and satellite. The latter is often the most economical choice because these devices default to using cellular networks when available and seamlessly switch over to satellite when they are not, all without breaking the active data connection.

Depending upon the specific needs, satellite networks can include devices and/or terminals and service plans that support various bands of satellite connectivity (L-band, C-band, Ku-band and/or Ka-band), and, like cellular services, use a platform for connectivity, provisioning, billing and device management.

Satellite Technologies

Satellite technologies vary from low throughput, low data rate, to higher bandwidth, real-time applications.

Satellite store-and-forward

- Dual-mode cellular and satellite connectivity with automatic and seamless fail-over between the two networks allows for least-cost routing benefits
- Low data rate service ideal for remote management of mobile assets like tracking and telemetry
- Burst-mode communication and gateway for store-and-forward messaging are often suitable for mission-critical applications

Satellite Broadband IP BGAN (Broadband Global Area Network)

- Standard IP high-speed, real time service (downlink and uplink speeds of high-end BGAN terminals are up to 492 Kbps)
- Provides standardized 3GPP IP real-time, intuitive data management capabilities with built-in robust security

Specifications for satellite IoT devices vary. Some important factors to consider when choosing a device include: the device environment, mechanical packaging, interfaces, certifications, country regulations, and power. Some devices offer built-in solar batteries when power supply is a challenge.

6 considerations for IoT satellite devices

What you need to know about your satellite-based IoT devices:

1. Country regulations
2. Power sources
3. Deployment environment
4. Mechanical packaging
5. Interfaces
6. Certifications

What to consider when choosing your IoT network

Building a successful IoT solution is all about matching your connectivity needs to the right technology or mix of technologies. Whether you choose one network technology or take a multi-network approach, you want the path forward with the best blend of coverage, performance, and value.

Key Decision Criteria

Depending on your IoT application, you may choose to weigh the importance of the key decision criteria differently. For example, one factor may be more important than the other based on the deployment environment of your IoT device. However, during the discovery phases of your network selection, all are important considerations to help you reach a successful final decision.

Coverage

The three IoT wide area network categories discussed in this report (broadband cellular, satellite, and LPWA) demonstrate that coverage can be very different for IoT devices based on their environment. Some devices are on the move frequently and need the breadth and scale of the cellular network. Others are so remote that only satellite services can effectively communicate with the IoT device. In the case of LPWA, these IoT devices can often be shielded by basements or walls when installed in subterranean environments. Regardless of the network technology, each option can have pros and cons based on the location of the IoT device.

Mobility

Knowing whether and how your IoT devices will be moving is essential for technology selection. Each wireless network technology has a range or distance that limits a device's ability to communicate to network access points. Some technologies work best for fixed locations, others can support limited or low speed movements, others support full mobility with high speed session hand offs among access points.

With cellular, LTE-M, and NB-IoT, devices can move seamlessly throughout a wireless network without interruption. Cellular-based roaming technologies also provide global coverage for IoT devices. These are important advantages for cellular communications, and now, with dual-mode satellite and cellular devices, mobile flexibility can be provided for satellite services too. That said, not all IoT devices need mobility.

Throughput

Throughput represents the rate (or speed) at which data can be exchanged over a network. In IoT, the throughput needs vary greatly across the wide variety of IoT applications. If your needs are targeted at Smart City parking meters, tolls, lighting management, or other scenarios where data exchange is minimal and may be managed using controlled time intervals, then high throughput may be a lower priority in your decision making. If your application is targeted at streaming media, telemedicine, or scenarios that involve video, a high throughput network will be essential. IoT use cases for HD video may drive mobile throughput advancements. Future 5G standards are anticipating new technologies like Millimeter Wave to accommodate greater speeds[8].

Latency

Network latency refers to the length of time it takes for the exchange of information to travel from one point to the next. Depending on the application, latency needs can differ. For example, a voice call requires very low latency for a quality conversation to occur. In IoT, applications that require critical response times for alert or notification procedures may also need low latencies. In many other situations, IoT devices may operate on scheduled or interval data transmissions that are not urgent. These applications are often accepting of higher latency.

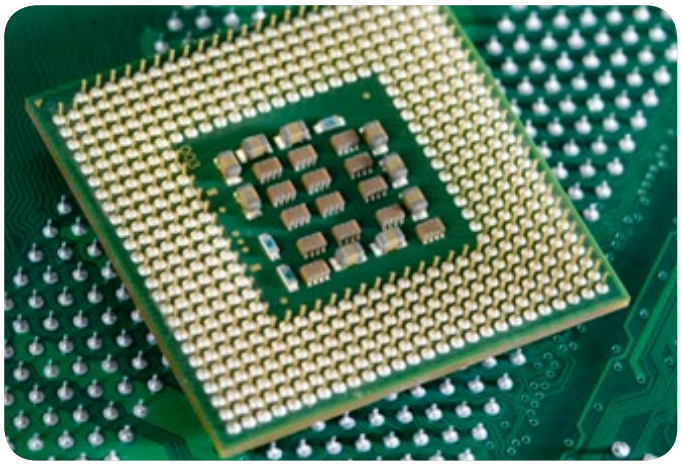
Several factors can affect latency:

- Hardware
- Software
- Type of connectivity
- Distance
- Network congestion

Battery

Maximizing battery life plays an important role in the design considerations for IoT devices today and future innovations. While devices like consumer wearables may find a battery life of 12 to 24 hours to be enough, remote asset monitoring devices need much more. For example, autonomous, recharge-able devices that are tracking assets in the supply chain may need anywhere from 7 to 30 days or more depending on the transit time or whether the device is traveling by land, sea, or air. In some cases, weather conditions play a role. Assets that are deployed in locations with cold, harsh weather conditions often experience adverse effects on battery life. In a worst-case scenario, when IoT devices are deployed in areas where a constant power source or frequent recharging is unfeasible, the business case driving the reason for connectivity may be negatively impacted.

Extending battery life from days to months to years can enable more and more things to be connected to the Internet. Earlier in this report, we discussed the importance of LPWA devices extending battery life for up to 10+ years. In addition, LPWA technologies are also being invented to support this long life on small battery form factors. For more information, see recent news from Ericsson, AT&T, and Altair[9].



[8] Millimeter wave is an undeveloped band of spectrum between 30 Ghz and 300 Ghz that can be used for high-speed wireless broadband communications

[9] http://about.att.com/story/att_and ericsson_boosts_iot.html

Cost

Cost is a major factor in virtually every project, and for IoT can be grouped into two primary categories:

- Hardware and deployment costs – These costs are the physical components and accessories of the IoT device and the associated costs of solution deployment. From an IoT module perspective, the industry is seeing a drop in prices. For example, AT&T recently announced advanced LTE modules at the low cost of $14.99[10].We expect that LTE-M modules will be even lower.
- Recurring costs – Services costs that include network services, management platforms, cloud data storage, maintenance and logistics, and security.

Interoperability

Leveraging assets like hardware, software, wireless networks, applications, and devices across various network providers is an increasing advantage in the global marketplace. Device Original Equipment Manufacturers (OEM's) who can sell to multiple companies worldwide can often provide lower-cost solutions thanks to economies of scale. MNO partnerships that can use each other's existing infrastructure are able to offer broader service coverage areas with less individual capital investment. Interoperability standards help ensure efficient and effective data exchange across these relationships, so that OEM's and other industry players are motivated to drive innovation, thus reducing cost structures, and broadening portfolios—all good things for customers.

[10] Plus applicable taxes and fees. Announced June 16, 2016.

[11] https://www.business.att.com/cybersecurity/docs/ exploringiotsecurity.pdf

Lifespan

The expected lifespan of a phone or tablet is often only a few years. However, in the enterprise IoT space, replacing devices every few years can be costly and impractical, especially for devices that are deployed in remote areas and require physical handling for upgrades. Firmware or software updates over the network are essential to enabling devices that require minimal human touch for maintenance. In addition, the long battery life with LPWA is expected to sustain device operation in the field up to 10 years or more.

Roaming

Satellite services provide connectivity to virtually anywhere on the globe. For full coverage, devices may rely on two or more satellite providers. Cellular technologies are available in most countries, albeit with different levels of deployment (3G, 4G), and typically offer the best roaming capabilities from one provider to the next. LPWA networks are not yet broadly available globally, but these technologies will come in both licensed spectrum and unlicensed spectrum forms.

Security

Security is the number one concern for businesses looking to take advantage of data from the Internet of Things. For enterprises, selecting a provider with a multi-layered approach to IoT security that can virtualize key security elements, protect the data flow between multiple platforms, and provide security consulting services (if needed) is more than a consideration, it's a necessity. For more insights in this area, refer to: *The CEO's Guide to Securing the Internet of Things*[11].

Choose Wisely

To help you assess which network is right for you, this connectivity matrix on IoT wireless networks can help you quickly review the four network types, their advantages and limitations, and our perspective on the scenarios for which each is best suited.

Success in the IoT marketplace ultimately could depend not on your device or app, but on choosing the right wireless technology, at the right time, to successfully serve a rapidly evolving market.

	Broadband Cellular	Licensed LPWA	Unlicensed LPWA	Satellite
Range/ coverage	AT&T overall wireless voice and data network now covers more than 99% of all American's[12]. AT&T offers global coverage[13] including 200 countries and territories	Cellular footprint In-building penetration and subterranean environments	Regional, limited In-building penetration and subterranean environments	Coverage virtually anywhere on earth
Throughput	Medium to high	Low to medium	Low	Low to high
Mobility	Yes	Yes	Varies	Varies
Latency	Ultra-low	Low	Varies	Varies
Battery life	Days to weeks	Up to 10+ years	Up to 10+ years	Days to weeks
Cost	Medium	Low	Low	High

[12]Based on overall coverage in U.S. licensed areas. Coverage not avail. everywhere.

[13]Global coverage claim based on offering discounted voice and data roaming; LTE roaming; voice roaming; and world-capable smartphone and tablets in more countries than any other U.S. based carrier. International

Conclusion

At AT&T, we help companies of every size develop IoT solutions to lower costs, gain efficiencies, and improve competitive advantages. In the push to create the next great IoT solution, it's not enough simply to connect to the Internet of Things. You need to connect to the type of network that best fits the specific demands of your IoT devices. Whether your ultimate decision is based on cost, mobility, battery life, or global reach, we have an IoT network that can meet your needs. For more information on our complete suite of IoT solutions and services, visit us at *att.com/iot*.

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