WHITE PAPER:

# COMPARING IOT NETWORKS AT A GLANCE

## How Wi-SUN FAN stacks up against LoRaWAN and NB-IoT

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# Overview

**Increasing Internet connectivity capabilities are transforming the modern business environment, creating an unprecedented investment opportunity.** It is easier than ever to connect and monitor industrial assets, to increase productivity and negate unplanned downtime. Thanks to sensors in these assets, and the connectivity that links them to a remote application, a wealth of third party data and service integrations that are facilitated by the cloud can be leveraged.

For a sense of scale, consensus estimates for the Internet of Things (IoT) devices range between 20 billion and 30 billion in the early 2020s, worth around $5 trillion, with Arm saying that there will be a trillion connected devices by 2035. The Energy and Smart City markets are expected to account for a large proportion of the total, fueled by smart grid and advanced metering, as well as connected street lighting and environmental sensors.

While some fingers have been burnt by marketers' over-hyping, no-one disputes that we have entered the age of the IoT. Some industries are a few years into the adoption process, while others have yet to take the plunge and make it out of 'pilot purgatory'. In the early stages of adoption, however, the choice of wireless connectivity protocol is the most important decision to be made, and unfortunately, getting a balanced view of the market is still not straightforward.

*The choice of wireless connectivity protocol is the most important decision to be made.*

This initial choice will dictate how much bandwidth is needed, how long a battery-powered device will last in the field, and ultimately the total cost of ownership (TCO) of the given application. This choice will affect performance, scalability, reliability and interoperability, and so you need to consider the TCO carefully. Having to send engineers to visit a device once it has been deployed could completely destroy the business case; looming legislation could force you to kill a deployment if you cannot push a newly mandated update to them; whilst an increase in the network charges paid to an operator could negate margins entirely.

# How Wi-SUN FAN compares with LoRaWAN and NB-IoT

There is a plethora of choices for wireless connectivity, ranging from private networks you could deploy yourself using Wi-SUN-based technology, to fully managed services from network operators. The wireless protocols themselves all differ significantly, but the three that are most applicable to utility, smart city, and industrial IoT are Wi-SUN Field Area Networks (FAN), LoRaWAN, and NB-IoT (LTE Cat-NB).

Wireless Smart Ubiquitous Network Field Area Networks (Wi-SUN FAN) is an open specification based on the IEEE 802.15.4g specification, as well as other IEEE 802 and IETF standards. The Wi-SUN Alliance developed and promotes the specification, and manages the certification process ensuring that devices from multiple vendors conform to the specification and meet the requirements for interoperability.

## Mesh and Star Topologies

Wi-SUN FAN is a mesh network protocol, meaning each device in a network can speak to its neighbors, which allows its messages to travel a very long distance – hopping between each node in the network. Unlike indoor personal area mesh networks (PAN) such as ZigBee and Thread, the Wi-SUN FAN was specifically designed for a much greater scale of endpoints that will hop over much greater distances outdoors.

Mesh networks are distinct from the 'star' network topologies that people will be most familiar with, such as WiFi or LTE, where the end-devices orbit central networking infrastructures, such as access points or base stations. In a star network, the end-device nodes do not ever communicate directly with each other, speaking instead directly to the network infrastructure or a cell tower.

Mesh networks, like Wi-SUN FAN, when deployed with sufficient density, will have multiple paths back from the end-device to the backhaul network via a router (aka border router) that links it to the Internet of a private wide area network. If the usual route back to the gateway is blocked, the end-device should have plenty of other pathways available, providing excellent redundancy. In terms of coverage, this approach gets stronger with the size and density of the network, and generally, it is much easier to fill in a coverage gap with additional devices, which can then relay messages, than it is to deploy a new gateway to serve that black spot.

Star topologies require that the end-nodes have a connection to the network, and since smart meters and most IoT endpoints cannot be expected to move around to find reception, there are a lot of potential pitfalls for star networks in terms of obstructions from objects or buildings, whether permanent or intermittent. The solution to these obstructions is, put simply, heavier investment in the network infrastructure, by adding additional base stations, which can be costly. Urban environments and their 'urban canyons' are some of the worst-case scenarios for network operators to tackle, while hilly rural terrain presents its own challenges. Furthermore, as the number of endpoints grows and device density increases, additional base stations may be required to support the increased traffic.

*Currently more than 95 million Wi-SUN-capable devices are deployed globally, operating in some very challenging environments*

## Wi-SUN FAN

Wi-SUN FAN is self-forming, which makes adding new devices to a network easy, and self-healing, so that if a pathway fails, the network will automatically re-route to the gateways. Currently more than 95 million Wi-SUN-capable devices[1] are deployed globally, operating in some very challenging environments and SLAs, proving Wi-SUN FAN's unique scalability and leveraging the capabilities of the meshing protocol.

Notably, Wi-SUN FAN is the most flexible technology and can adopt a hybrid approach, utilizing a mesh for dense networks, such as smart meters in a neighborhood, and then a star topology for linking assets deployed out in the field. Wi-SUN FAN operates in unlicensed spectrum; that is, the sections of the radio frequency spectrum not sold under licenses. The cellular mobile network operators are the most common licensed spectrum operators.

1 Navigant Research: https://www.navigantresearch.com/

## Key benefits of FAN Certification include:

- Offers adaptable multi-service networks that will help ensure interoperability today, and in the future.
- Reduces time to evaluate new products, as behavior, performance and interoperability are well defined.
- Eliminates single-vendor lock-in.
- Development of a global ecosystem of standards-based products, reducing the risk and costly impact of stranded assets.


For customers, FAN Certification ensures interoperability, which results in accelerated time to market.

## LoRaWAN

LoRaWAN is another unlicensed offering, which is based on a radio technology (LoRa) owned by Semtech – chirp spread spectrum (CSS), which uses a variable spreading factor to balance between higher data rate or a longer range. LoRaWAN is a Low Power Wide Area Network (LPWAN) technology, which is promoted and developed by the LoRa Alliance, to create a standard that is open on every level, except for radio devices, which use proprietary technology. You can buy radios directly from Semtech, as well as Microchip and STMicroelectronics.

Many of the early devices that were deployed using these chips were using code and software that was not part of the LoRaWAN stack, meaning that they are essentially closed-source private networks. The devices that are not using the full LoRaWAN stack are still using the LoRa silicon, but it is important to note that there is a difference between a LoRaWAN deployment and a LoRa one. LoRaWAN is closing the gap on LoRa, however, although shipments to proprietary LoRa networks still account for the majority of LoRa chip sales.

## NB-IoT

The third main technology in this sector is NB-IoT, also known as LTE Cat-NB. The nomenclature has shifted a few times over the years, but NB-IoT is a licensed spectrum LPWAN technology that is being deployed by Mobile Network Operators (MNOs). The 3GPP is the organization behind the standardization of the protocol, and the GSMA is the promoter alliance responsible for driving interest and adoption.

NB-IoT struggled on first release, due to its relatively high power usage compared to its rivals. The Release 14 revision to the 3GPP's standards has improved this challenge, and NB-IoT is now gaining ground on its LPWAN cousin LTE Cat-M, in terms of live networks. NB-IoT can be thought of as a stripped-down version of LTE, which does not support voice communications, and is best suited for static (that is, not mobile) deployments.

NB-IoT can also be deployed in the guard band of an MNO's spectrum allocation, which means it can be overlaid with an existing LTE network, or simply deployed in the older 2G and 3G spectrum that is being freed up. However, not every network operator is going to deploy NB-IoT, and full national coverage is entirely reliant on operators canvassing an entire country.

A business cannot yet deploy private NB-IoT networks, so availability is dependent on the MNO business case and the protocol's lifecycle. It has proven most popular in China, thanks in part to Huawei's heavy involvement in its development, and government subsidies. The cost of the end-device hardware is narrowing, but deploying a cellular base station is significantly more expensive than LoRa or Wi-SUN FAN, even before you factor in the cost of the spectrum licenses.

## Communication Performance: Bandwidth, Latency, and Bi-Directional Communication

It is not always useful to discuss the three main wireless protocols in terms of their specification sheets, as the most important characteristics are the requirements of the application itself. The number of messages needed to be sent, the indoor penetration needed, or simply the size of the battery, are all impacted by application-specific performance requirements you will not find on the datasheets, and so you must be wary of being misled by marketers.

However, Wi-SUN FAN does have higher throughput than LoRaWAN and NB-IoT, in conventional deployments, with the ability to provide quicker responsiveness and lower network latency for command and control applications. Wi-SUN FAN uses less power when sleeping and listening than rival approaches, and its higher throughput means that the devices spend less time on the air than their rivals, which equates to better power usage. LoRaWAN and NB-IoT are suited to applications with infrequent communication requirements, and while they are being used in some metering applications, questions about scalability, ongoing costs, and the ability to push firmware updates over the network are rife.


## Industry Standards

Selecting open standards will alleviate the fear of vendor lock-in – the scenario where your deployment can be held hostage by a single point in the supply chain. So, how do the three choices compare in this regard?

- **Wi-SUN Alliance** was established in 2011, and leverages IEEE 802.15.4g and IPv6. It is popular in utility and smart city applications, and enables devices such as smart meters and streetlights to interconnect onto a common network. Wi-SUN Alliance has more than 250 member companies that have collectively launched over 150 Wi-SUN-certified products. Wi-SUN Alliance devices and components are currently available from a wide range of vendors.

- **LoRaWAN** is a publicly available specification built on top of the proprietary LoRa radio design owned by Semtech. As such, it is not completely open, when viewed end-to-end, and, to date, Semtech has only provided limited access to its intellectual property. This means that the future of LoRaWAN is tied to Semtech's longevity, and in an age of increasing semiconductor consolidation, that is a bet that some might not want to take. LoRaWAN does have a diverse ecosystem of suppliers, but differing approaches mean that the devices and equipment are not guaranteed to be fully interoperable.

- **NB-IoT** (LTE Cat-NB) came into being in the Release 13 specification from the 3GPP, but has its history in technology that was developed by Neul and then acquired by Huawei. Its cousin, LTE Cat-M (LTE-M) can be thought of as a Nokia-Ericsson-Intel response to Huawei's technology, which has now resulted in two different approaches to a similar problem. Ratified in June 2016, there are now around 88 MNOs in 50 countries that support NB-IoT, although population and geographic coverage varies significantly between each one. Release 14 was ratified in the first half of 2017, adding upgraded versions of the two initial protocols – LTE Cat-M2 and LTE Cat-NB2.

## Security

The IoT security has become an important part of the discussion, with the Mirai botnet showing just how exposed our connected devices really are. The industrial and utility worlds have been rattled by BlackEnergy and Industroyer, while the lingering Huawei-USA dispute has cast a lot of uncertainty on the global technology stage. Wi-SUN Alliance aims to ease these concerns, by providing proven enterprise-grade security.

The key differentiator for **Wi-SUN FAN** is its native public-key infrastructure (PKI) integration, which provides security certification capabilities for each device on the network. This ensures that devices cannot be maliciously reprogrammed, certifying that incoming firmware updates are valid. This is especially important for devices that are going to be deployed in the field for years or even decades.

Another standout feature is the support for IPv6, and all the associated networking security features used in the Internet networking ecosystem – such as intrusion detection, traffic shaping, network analysis, and penetration testing. This allows Wi-SUN FAN to better mitigate denial-of-service (DOS) attacks, as well as maintain network visibility down to the end-devices themselves, better than its rivals.

There are, of course, ways to do this in **LoRaWAN** and **NB-IoT**, but at scale, it is much easier in the standards-based Wi-SUN FAN ecosystem. Thanks to strong support from silicon vendors, software specialists, and security experts, a range of industry-leading tools and components are available from a wealth of vendors, many of which are pre-integrated.

## Ecosystem

A healthy ecosystem is essential to the success of a networking standard. Competition is good for the customer, and with the support of the promoter alliances, the ecosystem should provide a wealth of interoperable products for use in the IoT application at hand.

- **Wi-SUN Alliance** – Wi-SUN Alliance consists of over 250 member companies, ranging from silicon and product vendors, software providers, utilities, academic institutions, government agencies and regulatory organizations. Each member contributes to the ecosystem, through a range of testing and certification programs for multi-vendor interoperability. Wi-SUN Alliance-compatible networks have 10 years of mixed-vendor environment experience.

- **LoRaWAN** – the LoRa Alliance counts more than 400 members, but it is unclear just how interoperable each member's products are within that ecosystem. This is complicated by the market presence of private LoRa devices.

- **NB-IoT** – as the most nascent of the three protocols, NB-IoT does not yet have a developed provider ecosystem. As a 3GPP standard, there is no practical barrier to it becoming as vibrant as the rest of the LTE sector, but there does seem to be an emerging pattern of Chinese NB-IoT versus the rest of the world.

## Power Efficiency

LPWAN protocols have enabled the deployment of battery-powered devices that can last for multiple years. However, the choice of protocol, combined with its message frequency requirements, will dictate whether you achieve three years or 10 years out of a battery. Lower power usage often entails a compromise in functionality, but with Wi-SUN Alliance, this is often not the case.

- **Wi-SUN FAN** – devices can be designed for frequent (from 10 second intervals) low-latency communication, drawing less than 2μA when resting, around 8mA when listening and less than 14mA at +10dBm when sending. The low-latency capabilities enable on-demand commands, rather than waiting for the devices to wake and receive or send messages from the network.
- **LoRaWAN** – devices are usually designed for infrequent communication (from 128 second intervals), drawing 2μA at rest, but 50% more than Wi-SUN FAN when listening – 12mA. Longer relative latency means less on-demand command capabilities.
- **NB-IoT** – devices are designed for infrequent communications, but with much greater relative power consumption. Peak current is listed as 120-300mA, with a sleep current of around 5μA.

## Scalability

Today's largest IoT networks will look small in five years' time. This is a market that is decades from true saturation, and initial investments can be expanded upon to great effect. Being able to add new applications to a network, such as environmental monitoring to a connected lighting deployment or demand-response to smart metering, could revolutionize TCO and ROI. To this end, the ability to grow a network is a crucial consideration.

*Today's largest IoT networks will look small in five years' time.*

- **Wi-SUN FAN** – Wi-SUN's mesh network can scale in both capacity and size, with its higher bandwidth making it easier to add more data-intensive applications in the future. Reliability improves as more nodes are added, with a number of Wi-SUN FAN compatible networks of several million devices. Wi-SUN FAN performs well in urban and rural deployments.
- **LoRaWAN** – expanding on an initial deployment may require new gateways, and resolving emerging black spots will require new gateways or the potentially costly step of over-provisioning the network in the first place. Cheaper hardware than NB-IoT makes this not as onerous a task, but there are concerns that in dense urban environments with lots of neighboring LoRaWAN devices, interference could be a significant challenge.
- **NB-IoT** – MNO rollouts are the biggest limiting factor for NB-IoT adoption. Customers will have to wait for coverage to be completed, and previous 3G and 4G experience illustrates that this can be slow and patchy. Whether MNOs prioritize these LPWAN initiatives or focus on more lucrative 5G densification, it will vary greatly by territory.

## Network and Device Longevity

A general rule of thumb is that IoT devices in higher performing networks will require fewer field visits, resulting in lower TCO, as even a single engineer's visit could negate the efficiency savings that motivated the deployment in the first place. Backwards-compatibility is another major influencing factor, and so when choosing a network, evaluate the ability to accommodate multiple generations of devices on that single network.

- **Wi-SUN FAN** – many Wi-SUN FAN networks deploy hardware designed for a 15-20 year lifecycle, battery included, with customers that operate multiple different generations of devices on these networks, demonstrating both the backwards and forwards compatibility of Wi-SUN FAN.
- **LoRaWAN** – LoRa Alliance members claim that devices can operate for 10 years on batteries, the current yardstick for evaluating LPWAN technologies. These claims will need to be backed by commercial terms and proof that the technology will be supported for an extended period of time.

| IoT Network | Data Rate | Latency |
|---|---|---|
| Wi-SUN FAN | Up to 300 Kbps | 0.02 – 1 second |
| LoRaWAN | 300 bps to 62.5 Kbps, depending on spreading factor | 1-16 seconds |
| NB-IoT | Up to 140 Kbps Uplink, Up to 80 Kbps Downlink | 2-10 seconds |

*Backwards-compatibility is another major influencing factor, and so when choosing a network, evaluate the ability to accommodate multiple generations of devices on that single network.*

- **NB-IoT** – the Release 13 specification (Cat-NB1) could not achieve the 10-year measure, while there have been claims that Release 14 is now capable of this performance. Silicon optimization has improved, but the cellular variants are still thought to be power-hungry, compared to the competition. The cellular community is still chasing the higher-margin data-intense workloads, and it is not clear if there is great enthusiasm for pushing the envelope at this end of the market. MNOs that struggle to get any market traction are also more likely to stall build-out plans, for fear of losing any achievable ROI.

## Summary

**The IoT is enabling new solutions to both old and new business problems, thanks to the low-power capabilities that bring these solutions to new TCO price-points.** Cities, utilities, and enterprises are now able to better manage assets, operations, and business environments – in smart metering and smart grid distribution automation, as well as connected streetlight management and city traffic control where service level agreements (SLAs) are required.

This trend is still accelerating, and because many companies have yet to take their first big steps, it is important to understand the key technology choices in this sector. For many applications, the security, coverage, ecosystem, and scalability assessments favor the characteristics of Wi-SUN FAN.

# Use Cases: City of London

The City of London, the historic heart of the UK's capital city, had struggled with integrating new architectural projects with the area's medieval street pattern. The narrow streets, alleys, and hidden areas provide its characteristic historical feel that is somewhat unique to London. However, it creates large urban canyons, where the tallest buildings sometimes block out the horizon.

The City is a centre of commerce, and one of the largest financial hubs in the world. Because of this, a large proportion of the daytime population does not live within the City of London itself, and resides outside the Square Mile at night. Its tourism attractions compound this problem, and the City of London itself has only 9,400 permanent residents – with around 450,000 people in the City at the busiest times.

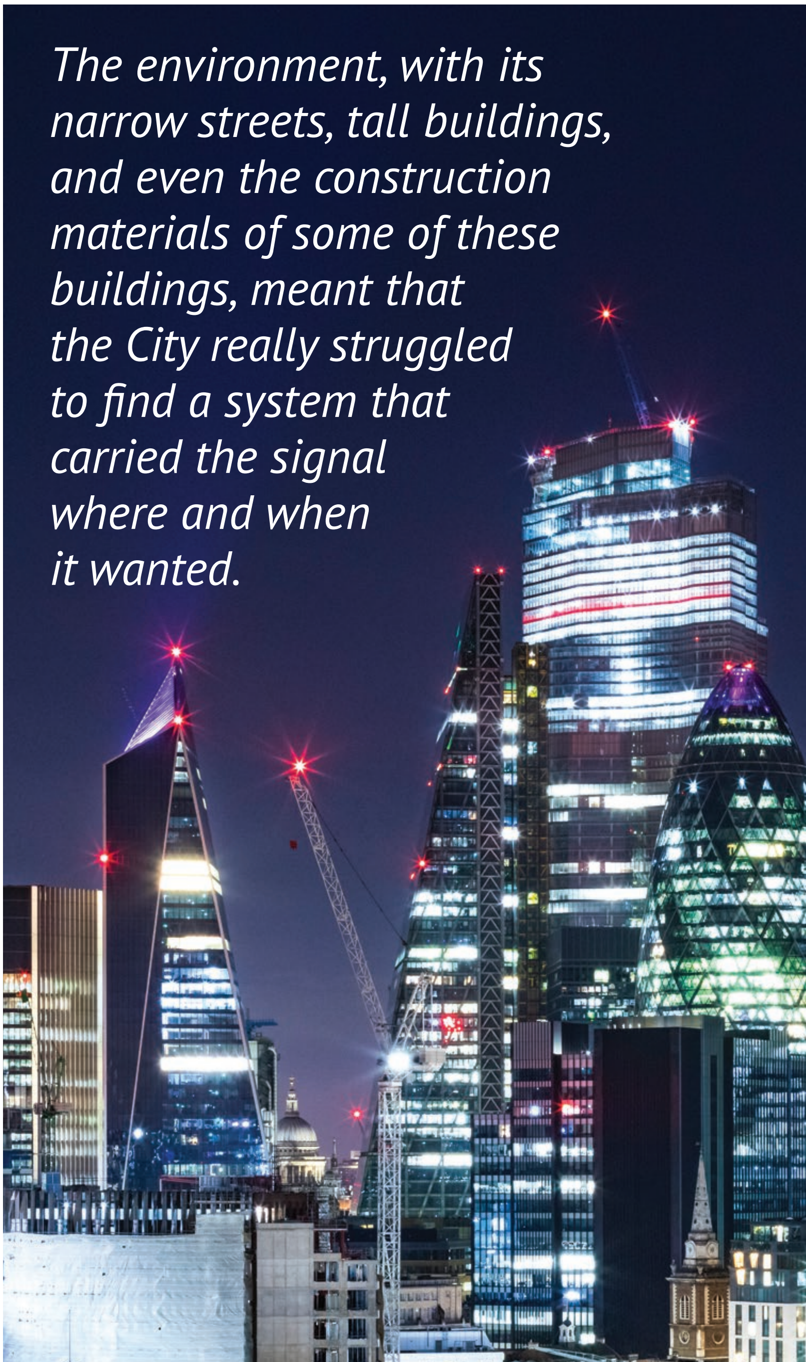
This makes accommodating and moving these people within the medieval footprint and urban canyons challenging. The City of London uses the term 'conflict area' to describe the areas that are most difficult, and uses street lighting as a solution to this problem. However, it has been compounded by the age of its lighting stock, with much of it over 30 years old and reaching the end of its useful life.

This led to a project being planned to replace the old units, as well as embrace new technologies to reduce maintenance costs, energy consumption, and to complement other programs run by the City, such as environmental monitoring. LEDs and a Central Management System (CMS) would also allow the City to be able to set the scene of its historic assets, using the tunable settings of digital lighting that are not so easily achievable using analog lights. Adaptive visual design was a key requirement.

The procurement process and trials discovered that the environment, with its narrow streets, tall buildings, and even the construction materials of some of these buildings, meant that the City really struggled to find a system that carried the signal where and when it wanted.

The City of London partnered with Itron and UrbanControl to meet these requirements, and was won over by the open standards that would allow them to work with any third party to integrate new devices. Examples of these include traffic and parking monitoring, occupancy sensing, environmental monitoring, asset management, and of course, lighting control.

Itron's Wi-SUN Alliance offering won out, thanks to its in-field performance and open standards support. Some 12,000 lights are being deployed in a two-year project that should be complete in 2020, supported by 10 gateways, using Wi-SUN FAN's self-forming and self-healing functions to add devices to the network, as well as UrbanControl's software-based security offerings to comply with the City's stringent requirements.


*The environment, with its narrow streets, tall buildings, and even the construction materials of some of these buildings, meant that the City really struggled to find a system that carried the signal where and when it wanted.*

## Case Studies:

**1** **A Northern European city, with a population of nearly 600,000, used a Wi-SUN Alliance powered network to reduce energy costs, increase road safety, and promote cycling as part of a citizen health initiative. The city council was looking to integrate city services into an Open Data platform, collating over 60 different organizational data streams.**

Focused on street lighting automation, the city used automated brightness adjustment to match lighting levels to environmental conditions, as well as to vehicle, bicycle, and pedestrian traffic. Wi-SUN-enabled lights and control nodes were paired with cameras and noise sensors, to achieve a 60% energy saving, as well as provide nearly 3,000 data sets to the Open Data platform – that can be used by third party developers in smart city applications.

**2** **A Northern European capital city, with a population of just over 600,000, is implementing a carbon-neutral initiative with a 2025 deadline. Energy usage, traffic management, and emergency responses are applications that are being targeted, with a Wi-SUN Alliance-enabled street lighting system being deployed. Some 20,000 new lights are being installed, and the network will be used by other smart city applications.**

Motion and occupancy sensors are being used to automate the brightness levels of the streetlights, as well as provide safer intersections for cyclists, which have achieved a 55% energy saving and a 50% reduction in operations and maintenance costs for the lights. A smart city development lab has access to data derived from the network, and the city is building an Open Data hub for other developers to use to improve citizen services and quality of life.

**3** **A major city in Mid-West America, with a population of around 2.7 million, has utilized Wi-SUN Alliance to deploy over 100,000 connected streetlights, as part of a major modernization project. With a target of adding nearly another 200,000 units, it will be one of the largest such deployments in the world. It is projected to save city taxpayers over $100 million over the next decade.**

The new system will be able to diagnose outages, eliminating a major source of citizen dissatisfaction, as well as the need for citizens to self-report. The city targeted areas with heightened public safety concerns for the first-phase deployment, so that these communities can enjoy the benefits provided by modern street lighting. This includes less light pollution, thanks to dimming controls and the ability to angle these lights towards the places they are needed, without flooding the night sky.

**4** **A major utility in Mid-West USA with over 4 million electricity customers has responded to a state-mandated infrastructure modernization requirement, using Wi-SUN Alliance as a core component of its 10-year, $2.6 billion investment plan. The utility will achieve operational cost reductions of $100 million annually, a 48% outage duration reduction, and avoid 7.1 million customer interruptions, thanks to the smart grid upgrades.**

Some 4 million smart meters have been deployed, with around 6,300 Distribution Automation units too – which were completed some three years ahead of target. The network served as the basis for a smart streetlight pilot project, and once deployed at scale, the lighting system is expected to reduce costs by 65%, as well as improve the resiliency of the mesh network.

*For more information on Wi-SUN Alliance and its role in the future of the IoT, visit www.wi-sun.org.*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