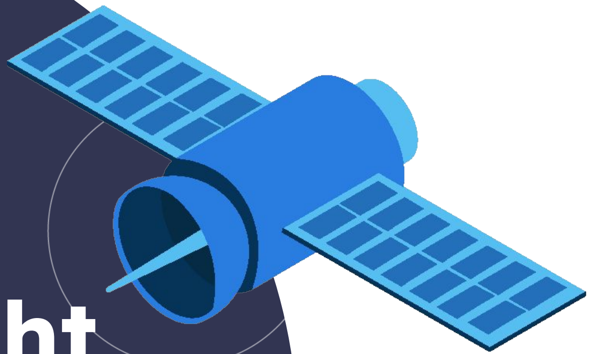
Ground Control

# How to Choose the Right Satellite IoT Network

## for Your Remote Application



# Introduction

If you have a remote application you need to be able to talk to - environmental monitoring devices, for example, or an unmanned system - you've never had more choice in terms of connectivity.

New satellite constellations are being launched at a faster rate than ever before, and with them, new services and standards. The established satellite networks have responded by diversifying their services, offering greater flexibility which is frequently coupled with more competitive pricing.

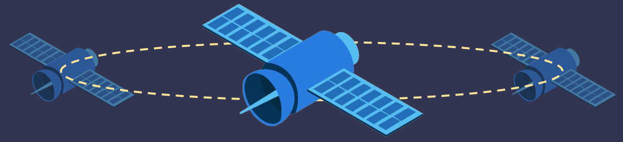
This is broadly great news, but presents two new challenges for systems integrators and IoT engineers: how to choose the most appropriate service, and through which satellite network.

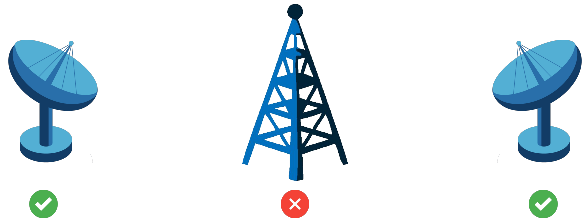
Ground Control is not a satellite network operator.  Since 2003, we've built connectivity solutions that leverage satellite networks - testing multiple services and networks to ensure that our customers get the best return on investment for their individual needs. This makes us uniquely qualified to outline both what questions you need to ask in order to land upon the right connection, and to make recommendations based on our experience.

That's what this eBook is all about; we'll equip you with the considerations you need to take into account when selecting a satellite IoT network, **so you can save time and money, and get the best results from your remote application.**

# Why Use Satellite IoT Connectivity?

The most obvious reason to choose satellite is coverage. If there's no cellular infrastructure, and creating an unlicensed **LPWAN (i.e. LoRa)** isn't feasible, satellite is a practical solution.

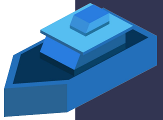




In addition to being globally available, satellite is extremely reliable, so it's an excellent choice for a failsafe communication method. A customer of Ground Control's operates an international gas pipeline, and in order to safely run production, they need to receive sensor data from two out of three of their connectivity channels. **They have two satellite links, and one cellular link; in the 18+ years they've operated this system, neither satellite connection has ever failed.**

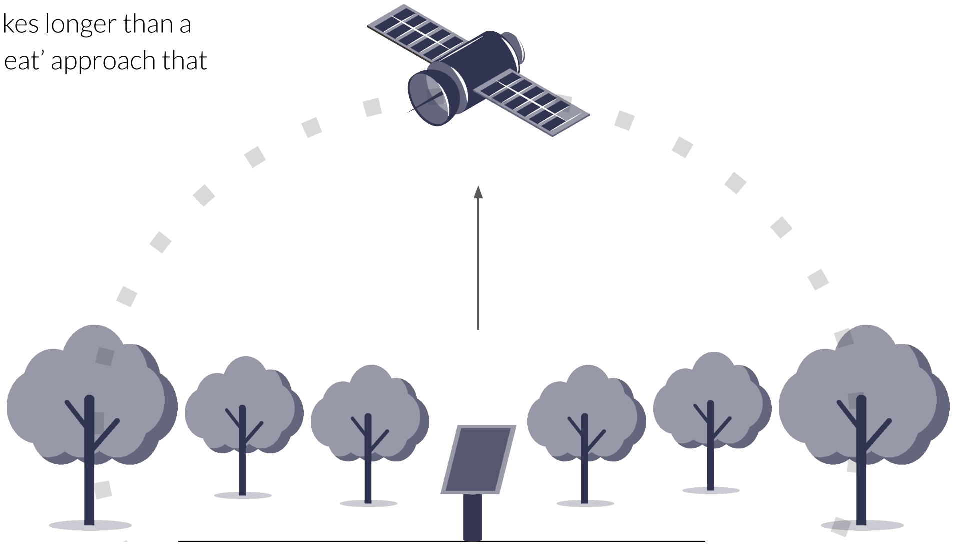
It's also very secure, and is sometimes deployed ahead of a lower cost, terrestrial option purely because the data being transmitted is particularly sensitive. **We're seeing rapid adoption of "air-gapped" satellite systems in critical national infrastructure,** to mitigate vulnerabilities that have become increasingly attractive to terrorists.

Plus, there's no roaming needed. While strides have been made to improve roaming agreements for cellular, it's still a challenge, with many countries restricting permanent roaming, and requiring a local SIM. Additionally, cellular IoT technologies like LTE-M and NB-IoT have immature roaming agreements; getting a single cellular SIM that's 'access all areas' just isn't possible.



Once you're connected to a proprietary satellite network, however, you don't have to worry about localities; **your mobile application will remain connected wherever it goes.**

Of course there are drawbacks. Moving data to a satellite and back to Earth takes longer than a terrestrial network, plus it's more expensive - it's definitely not the 'all you can eat' approach that some engineers have grown accustomed to with cellular IoT!

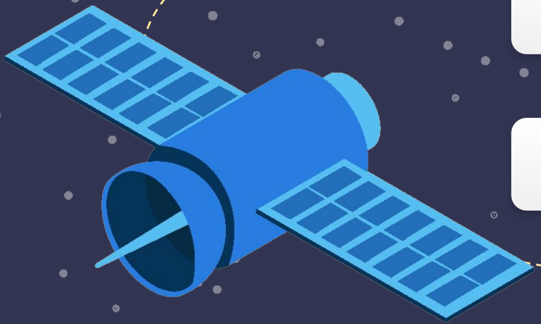


**You will need to factor data constraints into your infrastructure design to both save money and conserve power.**

Further, while satellite coverage is global, you do need to be able to see the sky. Very few satellite solutions will operate indoors. In some scenarios, where you position your satellite antenna will have a material impact on the efficacy of the service - we'll talk more about this later on. And some frequencies used by satellite networks are affected by 'rain fade' - they will work less effectively in poor weather conditions.

# Satellite Orbits and Frequencies

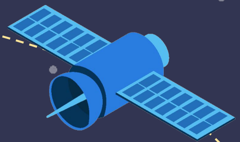
We're going to explore in more detail the implications of satellite orbit height on your IoT application later in this eBook, but as a quick primer, **there are three terms with which to familiarize yourself.**



**GEO**

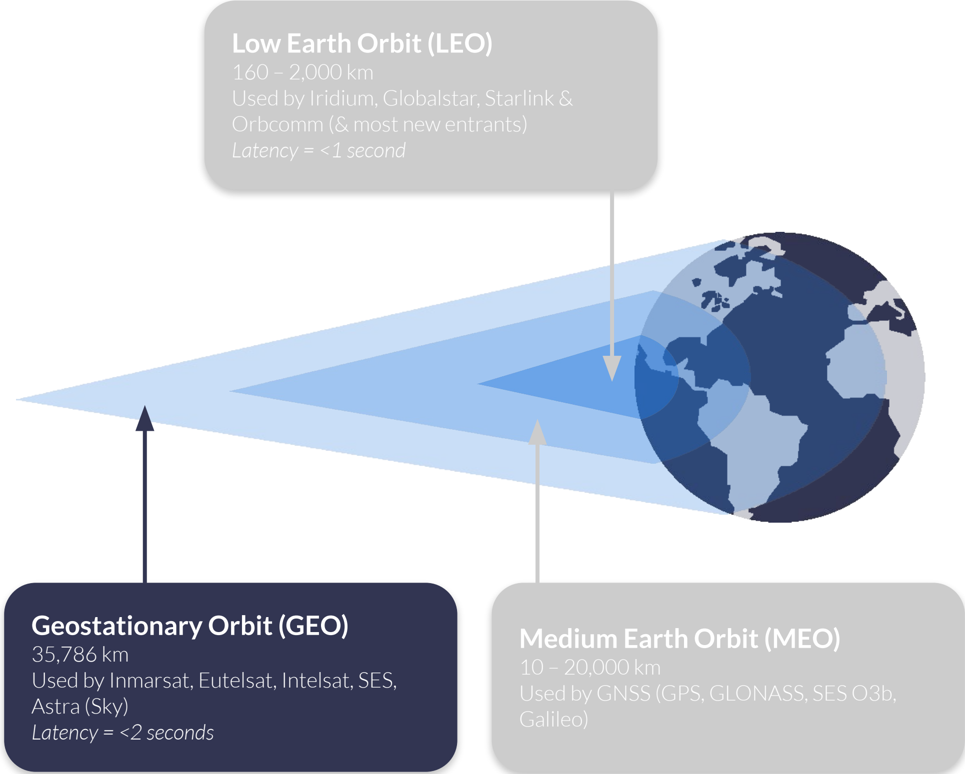
**LEO**

**MEO**



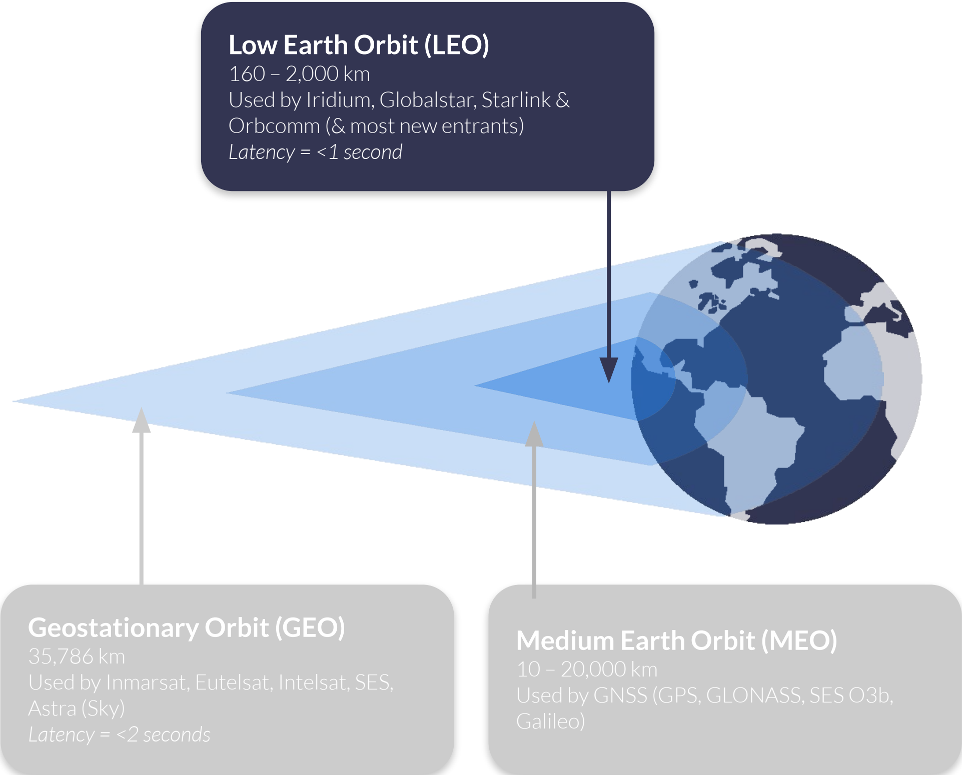
# Geostationary Orbit (GEO)

Satellites in GEO are 35,786 Km from Earth, and orbit at the same speed as Earth's rotation, making them appear to be stationary. Because of the distance from Earth, they can 'see' a huge amount of the Earth's surface - you need only 3-4 satellites to deliver almost global coverage (they tend to have blind spots in the polar regions). **The latency - the time it takes for a signal to leave Earth, reach the satellite, and return to Earth - is approximately two seconds.**



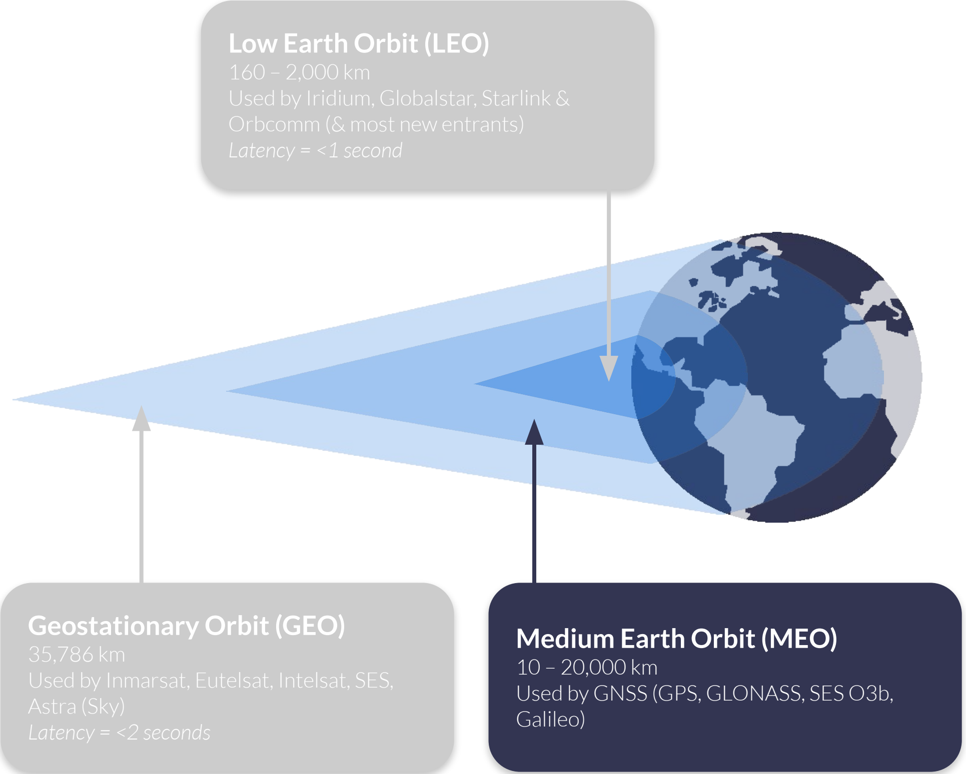
# Low Earth Orbit (LEO)

Most satellites are now launched into Low Earth Orbit; the launch costs are lower, and the latency is shorter, making them ideal for real-time communications. Each satellite can only ‘see’ a relatively small amount of the Earth’s surface, so you need more satellites in orbit if you want to deliver global, real-time connectivity; **Iridium, for example, has 66 satellites in LEO, and Starlink’s D2C service, when complete, will have well over 200.**



# Medium Earth Orbit (MEO)

Sitting between the two, MEO has largely been the preserve of the navigation systems (GPS, GLONASS etc.) but SES continues to launch satellites into MEO, and several other network operators have filed for MEO constellations with the Federal Communications Commission. **For the most part, these are designed for high throughput satellite internet services, however, rather than being intended for IoT applications.**



# Standards-Based vs. Proprietary

To date, to communicate with a satellite network, you need a modem that's specifically designed to operate with that network. These modules are not interchangeable; if you want to connect your application with the Iridium satellite constellation, you would need a different modem than if you decided on the Viasat satellite network.

While this does mean you're 'locked in' with a particular network, there are distinct advantages to this approach. Proprietary modems and the standards used therein are tailored to their particular network, and this means you can **pass a lot of data, very efficiently,** through this mechanism.

In recent years, efforts have been made to make terrestrial standards work over satellite. In the context of IoT, **we're referring to LTE Cat 1 and NB-IoT**. This would mean that a single modem would allow you to communicate both with a cellular and satellite network, significantly lowering the cost of the hardware as economies of scale kick in. In principle, it also opens the door to supplier switching; if several satellite networks are utilizing NB-IoT standards, you could move your business if you chose.

**This could open the door to greater competition over airtime, and lower pricing.**

These are developing technologies, however, and currently come with quite a few compromises. In the case of LTE Cat 1, it's pretty power hungry, **which is problematic for IoT applications needing to use battery or solar power.** In the case of NB-IoT, it moves really tiny amounts of data, so while it's incredibly power-efficient, you will be operating under great data constraints.

At the time of writing - early 2025 - standards-based satellite connectivity is in its infancy, and while we anticipate more services coming online this year, the cost-saving and supplier-switching benefits are likely several years away. Furthermore, the standards themselves need further development to make them work better with satellite networks, which adds further delays to widespread adoption.

**We will recommend standards-based solutions where appropriate, but it is important to note that it will be 2-5 years before these deliver on their promise.**

# Choosing a Network

There are **four key questions** that will help you narrow down the best network for your application.

**How data intensive is your application?**

**Is your application stationary or mobile?**

**Where are your sensors located?**

**How time-critical is receipt of your data?**

Some carry a good amount of nuance, whereas others are relatively straightforward.
**We'll cover each in turn.**

# 1. How data intensive is your application?

| TCP / IP | Messaging |
|---|---|
| Interactive<br>Two-Way<br>Relatively Resource-Heavy<br>Very Widely Used | Send Only Required Data<br>Send When Needed<br>Very Efficient Use of Airtime<br>May Need Engineering Work |
| **Examples** | **Examples** |
| Iridium Certus 100<br>Viasat IoT Pro (BGAN M2M)<br>LTE Cat 1 | Iridium Messaging Transport (IMT)<br>Viasat IoT Nano (IDP)<br>NB-IoT |

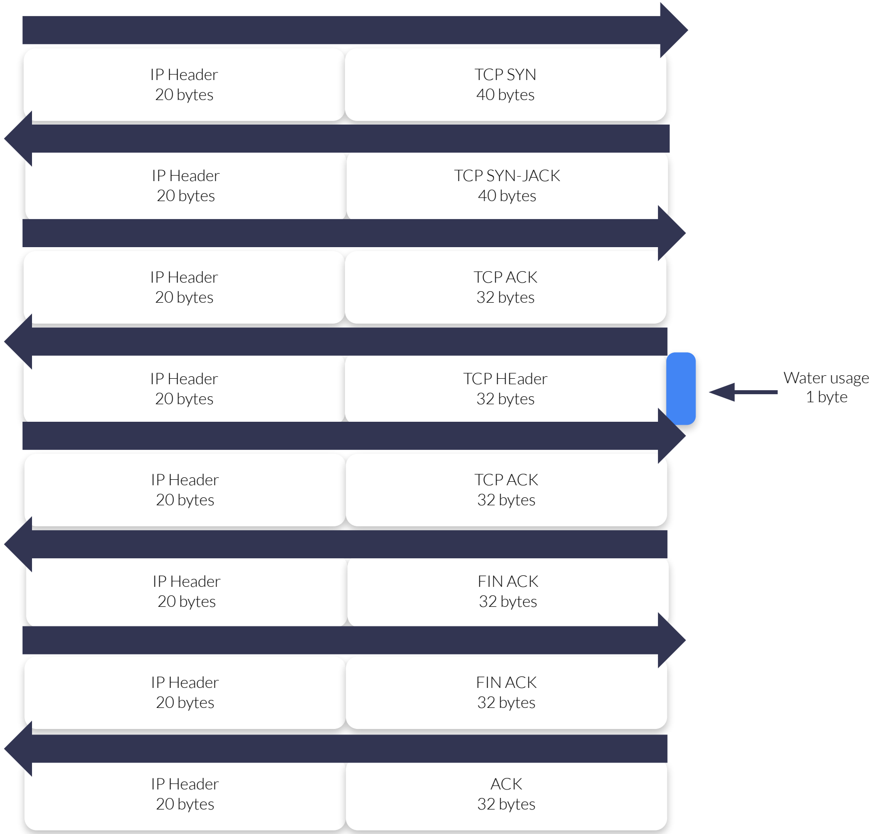
While TCP / IP is the most common means by which packets of data are transferred, it's inefficient when it comes to transmitting very low volumes of data, and it's resource-hungry.

In this example, you can see how much data is passed back and forth in order to send just a single byte of useful data (thank you to Nick vs Networking's blog post for this great illustration).

Not only are you paying for the extra packaging and overhead, it might also require more power to transmit than if you were simply transmitting the useful data. Not an issue if your asset / sensor is powered, but it could be if your asset is unmanned, and needs to run off a battery for several years in between maintenance visits.

**If you can avoid using IP, you can minimize the volume of data delivered, and in doing so, spend less money on airtime, while keeping your battery powered device running longer.**

With messaging, 100% of the data that is transmitted can contain useful application-related information, and the transmission lasts only as long as it takes to send that data. Compared to IP, it's like the difference between a text message and a phone call. Iridium's Short Burst Data (SBD) and Iridium Messaging Transport (IMT), plus Viasat's IoT Nano are all message-based.




*Source: https://nickvsnetworking.com/nb-iot-nidd-basics/*

It's an extremely efficient way to use satellite airtime: send only what you need, when you need it, with no costly overhead. It does present a data compression (or compaction) challenge for developers: the message sizes are minute, with SBD sending just 320 bytes, and receiving 270 bytes. That can take some creativity to work with – but necessity is the mother of invention! As an example, our SBD-based tracking devices convey date, time, position, altitude, course, speed, battery percentage, temperature, precision in just 17 bytes.

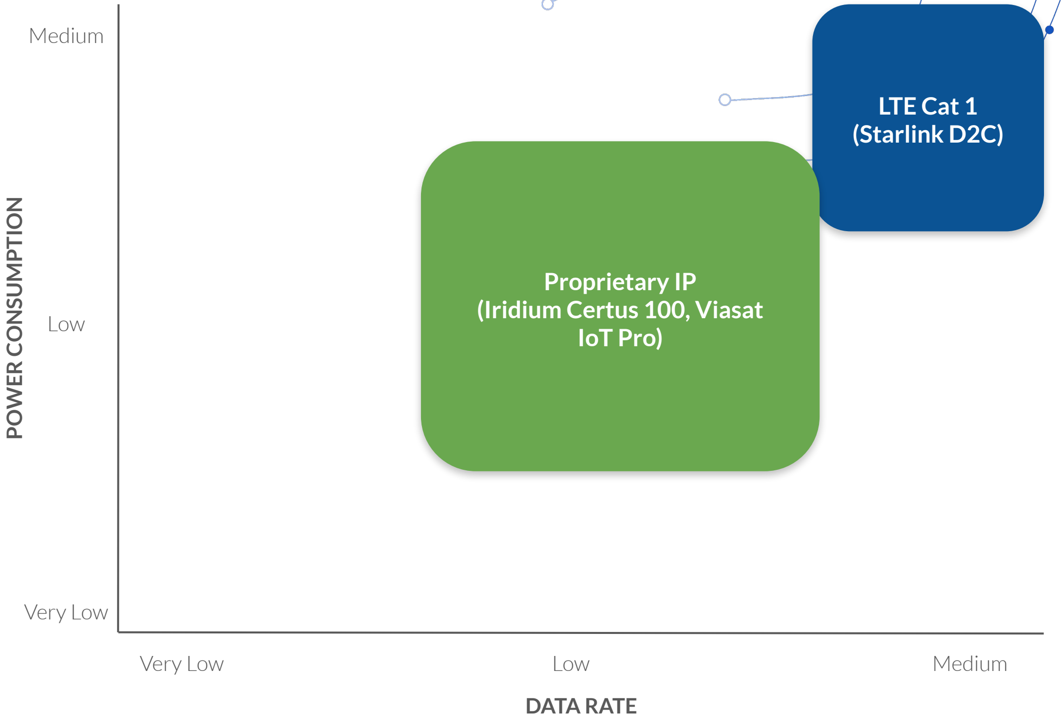
There are times when an IP-based option is necessary and optimal; **if you need real-time command and control of an unmanned system, for example, or if you need to stream video or image content.**

# IP-Based Services

Currently, your best options for an IP-based satellite IoT connection are Iridium Certus 100, or Viasat IoT Pro (previously called BGAN M2M). Both utilize proprietary technologies so while you're locked in to that satellite network, you can move a lot of data using relatively little power.

In the next 12 months, in some locations, Starlink's D2C service should become available.

This will let you move a lot of data, but it does come with a high power budget; ideal for trucks, trains etc. which will have a ready supply of power.

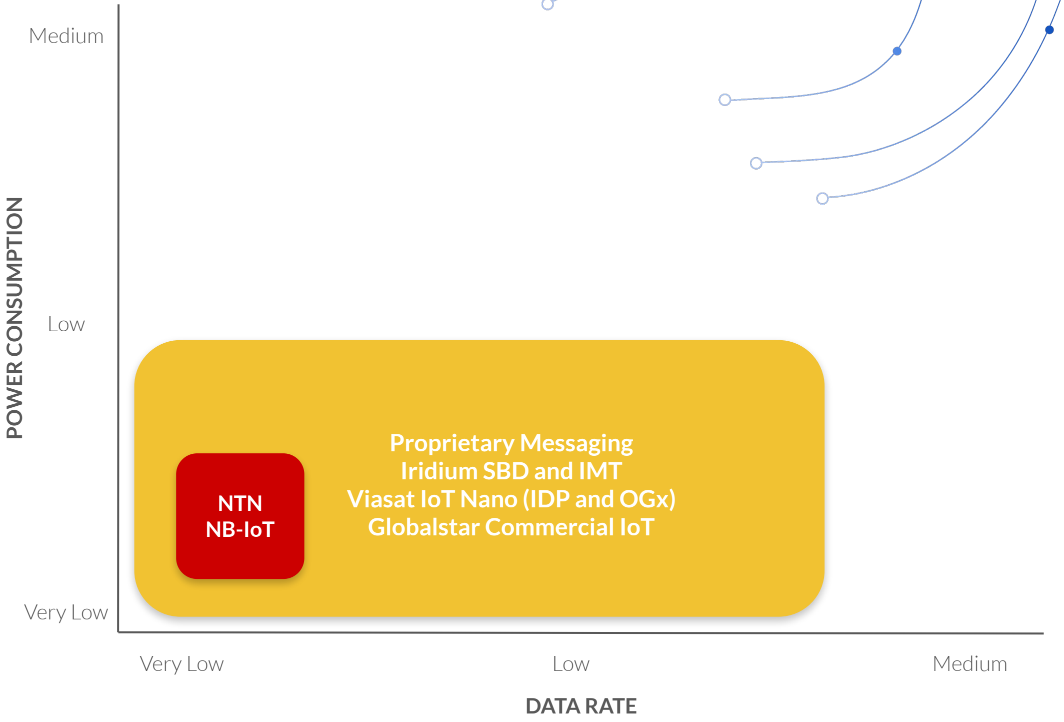


# Message-Based Services

As this is the most efficient means of passing data over satellite, there are lots of options available to you here. Iridium has Short Burst Data (SBD) for very small data volumes, and Iridium Messaging Transport (IMT) for larger data volumes. Viasat has IoT Nano (which combines the services previously known as IDP and OGx). Globalstar's 'Commercial IoT' service is also message-based.

In the 'coming soon' corner is NTN NB-IoT, which both Viasat and Iridium are working on, and is available in a limited capacity through companies like Skylo.

This passes extremely small volumes of data and uses very little power to do so, ideal for long term, simple sensor deployments.



# 2. Where are your sensors located?

Firstly, not all satellite IoT networks are truly global.
In fact, at the time of writing, **only one - Iridium - is.**

That said, many networks cover most of the Earth, leaving only the polar regions without cover; a quick check on network availability in your sensors' location is the first step.

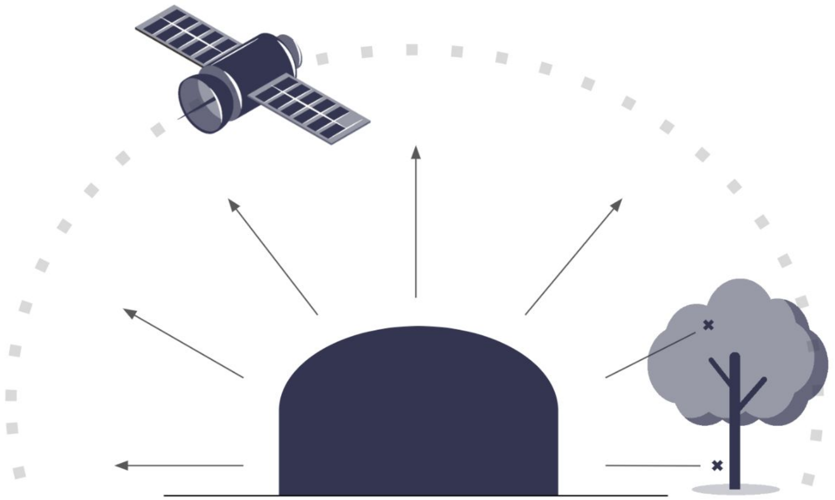
Next you need to consider more particularly where they're located. Will they be in forested / mountainous areas? Or farmland or open ocean?

**This is one of the areas where satellite orbit height has a bearing on your choice of network.**

If you choose a LEO network, you don’t need to point your antenna at the satellite. The satellite will be passing overhead, and so will capture the data as long as the antenna has a clear view of the sky.

If your antenna is, for example, situated on a vast plain with a 180 degree view of the sky, the satellite will have a close to real-time connection with the antenna throughout its passage overhead. If you have obstructions such as trees or mountains, then you just need to bear in mind that there will be short periods of time when the data isn’t being moved, because it can’t pass through the obstruction.

**As the illustration indicates, it will get through; but only once the satellite has ‘cleared’ the obstruction.**



LEO Constellations: Clear View of the Sky

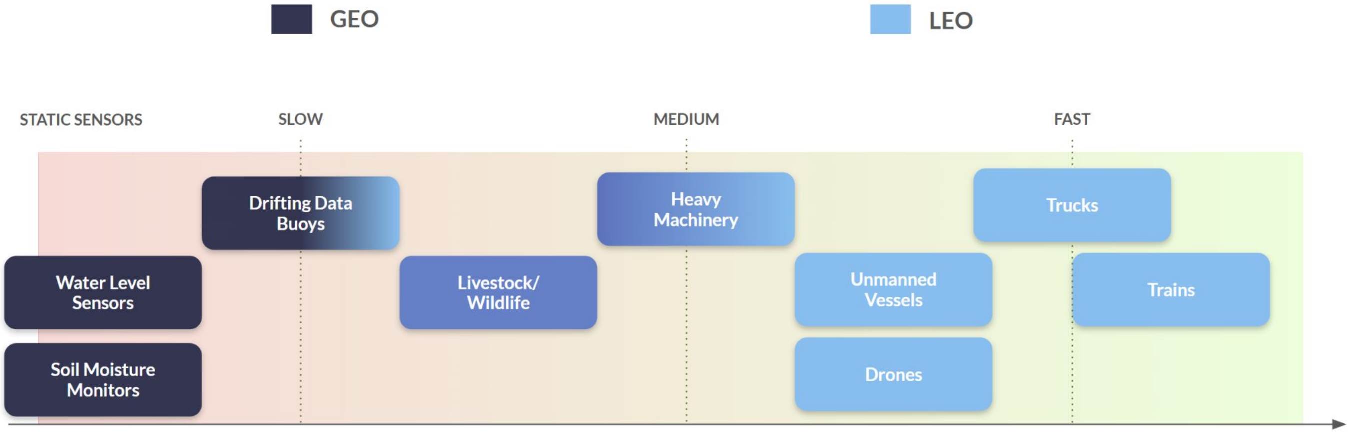
If you choose a GEO network, you need to point your antenna at the satellite - it needs 'line of sight' to the satellite. Many devices will help you figure out how well aligned your antenna is with the satellite (called the 'look angle') with a series of LED indicators or sounds. **Once you've appropriately located your antenna, as long as it doesn't move, it will retain a very stable connection with the geostationary satellite.**

However, if the satellite is, relative to your location, quite low in the sky, and you have obstructions like trees, buildings, mountains etc. to contend with, you will have some challenges getting the signal to the satellite. You can mount the antenna on a pole to get some height, or bounce the signal up to higher ground. There's often a workaround, but it may require some ingenuity and engineering skill - and it's worth noting that this isn't usually an obstacle for LEO-based hardware.

**GEO Constellations: Line of Sight**

# 3. Is your application stationary or mobile?

Following on from the above, if your application is moving rapidly, it's more likely to be moving in and out of forested, built-up or mountainous areas that could compromise its ability to talk to a GEO satellite network. **For this reason, LEO networks are particularly well suited to mobile applications, as you don't need to point the antenna to maintain a connection.**

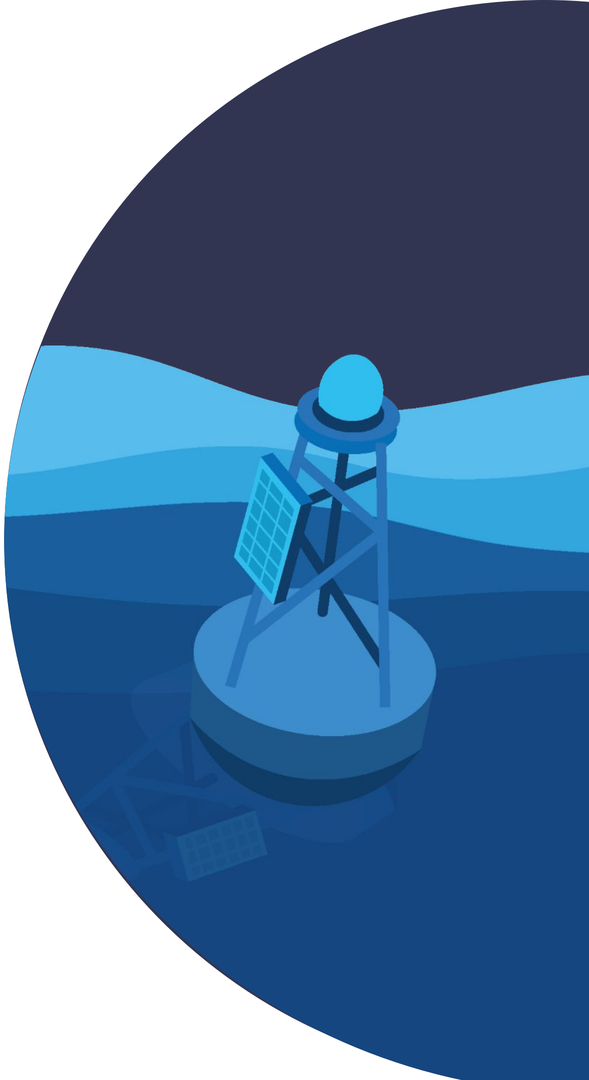


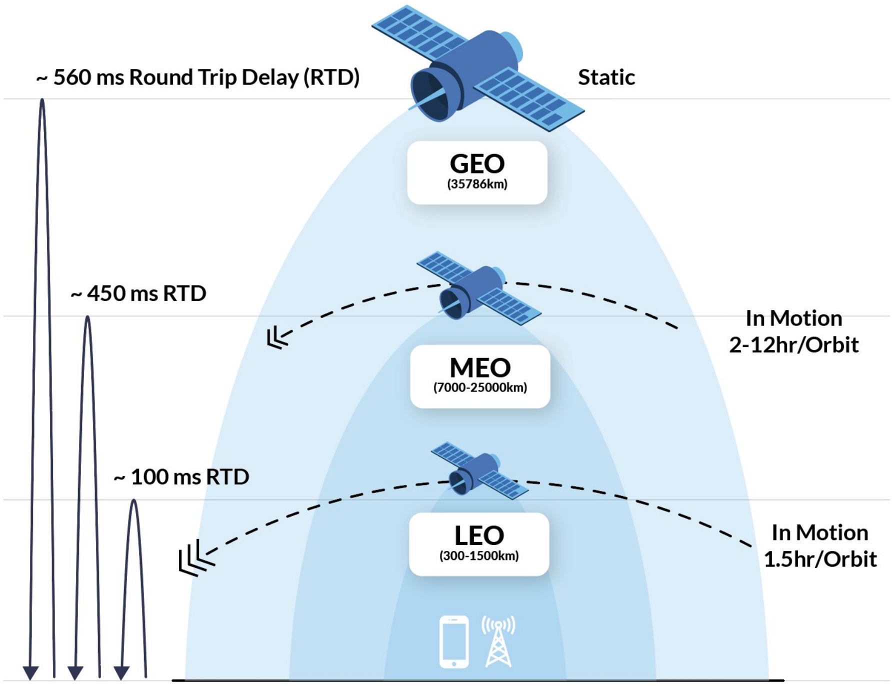
It isn't a hard and fast rule, but as a generalization, if your sensor is static - water level or soil moisture monitoring, for example - and you have established that you have line of sight to a GEO satellite, this will be a solid, reliable and very economical means of moving your data.

You can also use LEO satellites for stationary applications, of course, and many people do; they have the benefit of working well across both stationary and mobile use cases.

**Similarly, you can use GEO satellites for mobile applications - particularly if they're not moving around too much.**

Many GEO devices have auto-pointing antennas that will relocate the satellite automatically, and as long as there aren't obstructions - for example a USV or drifting data buoy - this solution could work perfectly well.






# 4. How time-critical Is receipt of your data?

As mentioned previously, the satellite orbit height has a bearing on how quickly your data can be transmitted, with satellites in GEO having more than double the Round Trip Delay of satellites in LEO.

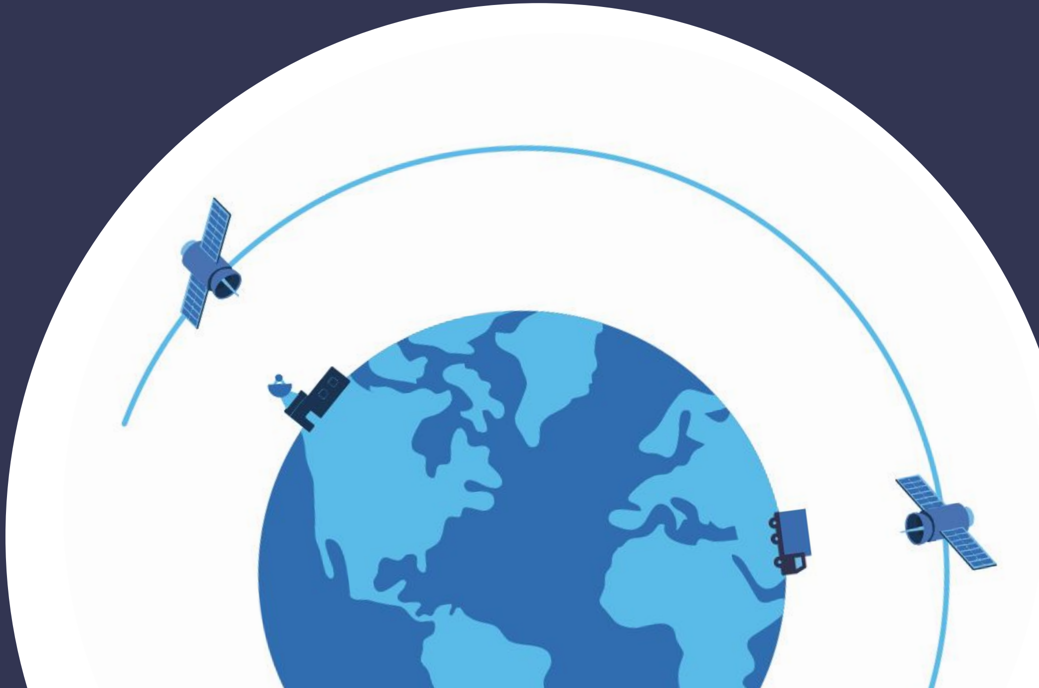
This graphic represents the maximum possible speed, and requires both an IP connection and satellite availability. If you need fast, real-time data delivery, you will need a combination of a well established LEO satellite network, and an IP-based connection.

**However, if you can manage with just a few seconds' delay, you unlock substantially more options: the ability to use a message-based service, and the ability to use a GEO network.**

What do we mean by 'well established LEO satellite network'? This is an important point: there are several new satellite networks in LEO who are offering really competitive pricing for both devices and airtime. However, they have only a small number of satellites in orbit. **This means that they are using store-and-forward technology to move your data; effectively, the orbiting satellite collects your sensors' data when it passes overhead, and then will transmit it to the ground station when it comes into view.**

There is no problem with this approach if you can wait several hours for your data, and indeed, it's a great choice for less critical IoT applications such as monitoring soil nitrogen levels on a remote farm.

**But it is important to remember that just because a network is in LEO, it doesn't mean you're going to get your data quickly;** there needs to be sufficient volume of satellites for the operator to be able to offer real-time transmissions.



# Case Studies

While we've simplified the process as much as possible, it's still a complex set of decisions.

**So we'll sign off with a series of case studies to bring this to life.**

Case Study:

# Soil Moisture Monitoring in Scotland

- **Application is stationary**
- **Geography is a combination of rolling hills, plains and forests**
- **There is some cellular infrastructure but this is unreliable**
- **The power supply is solar**
- **Data is requested every 12 hours**
- **Data volume is low but the customer is used to working with TCP/IP, and would prefer to continue to do so.**

With a stationary application that's not at an extreme north or south latitude, the GEO satellite constellations are a possibility; the leading GEO network for IoT applications is Viasat. The terrain may be problematic for line of sight to a GEO satellite, so careful siting of the antenna would be required. **But once a GEO connection is established, it's both stable and economical.**

With low data volumes and infrequent transmission times, in principle it would be possible to explore a message-based transmission; either Viasat's proprietary service, IoT Nano, or their soon-to-be-released standards-based service, IoT Direct. However, the customer has a strong preference for a TCP/IP-based transmission, which leads us to the Viasat IoT Pro (previously BGAN M2M) service.

With some limited cellular access, ideally we'd choose a device that could switch between cellular and satellite depending on service availability - this will save money for the customer. There are several satellite IoT devices that will work from solar power and switch between cellular and satellite on a lowest-cost routing basis: in this instance we recommended the Hughes 9502.

There's usually one or two key requirements that steer the choice, and in this case, it was the customer's strong desire to have a TCP/IP connection. The alternatives to Viasat IoT Pro service would have been Iridium Certus 100, or Starlink's D2C service. In the case of the latter, it's overkill from a data transmission standpoint, and would drain too much power. In the case of the Iridium Certus 100 service, for the specific data volumes this customer needed, it would have worked out slightly less economically.

Network: **Viasat**

Service: **IoT Pro (BGAN M2M)**

Device: **Hughes 9502**

## Case Study:

# Water Level Monitoring in Northern Canada

- **Application is stationary**
- **Geography is forested and with some building infrastructure**
- **Zero cellular infrastructure**
- **Power supply is battery plus solar panels - but needs to operate unmanned over the Canadian winter**
- **Data is requested every 12 hours, but also whenever water levels fall out of predefined parameters - so some degree of compute power on the device is needed**
- **Data volume is variable, but usually relatively low**
- **Customer can work with a message-based transmission.**

In this instance, the far north location of the sites wasn't ideal for a GEO based network. The satellite was very low in the sky, and with forests and buildings to contend with, it wasn't possible to establish a clear line of sight to the GEO satellite. So we knew we would be working with a LEO constellation.

The biggest challenge here was that the device needed to draw as little power as possible, as the solar panels would be largely ineffective over the long Canadian winter. A message-based service is the most efficient way to pass data over satellite. While there are several services available, the other key element was that the sensor needed to be able to send an alert in real-time if water levels moved above or below key parameters.

This narrowed down the field to Iridium, because it has the most mature LEO IoT network, with global coverage and real-time connections. Iridium doesn't yet have a standards-based service, but has two proprietary message-based options: SBD, which passes small volumes of data very economically, and IMT, which is the better choice if you need to pass greater volumes of IoT data - aggregated gateway data, or photos / compressed video, for example.

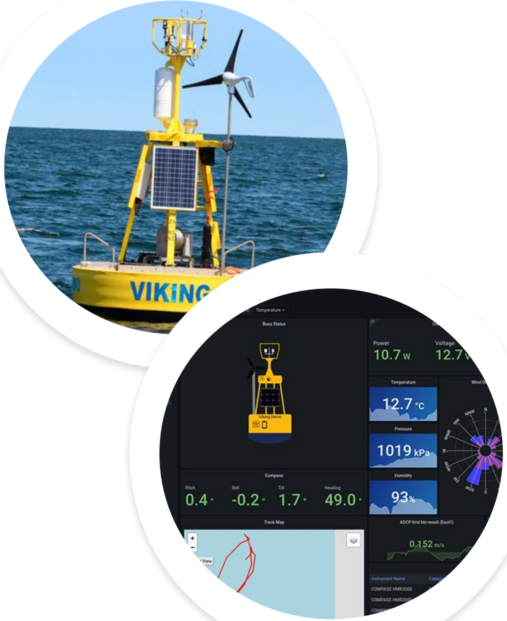
As the customer's data requirements were low, we selected the SBD service, and a device with edge processing capabilities (to manage the alert parameters) that could run on battery for several months.

Network: **Iridium**

Service: **SBD**

Device: **RockBLOCK Sense/Switch**

# Case Study:
# Oceanographic Data Capture Through Buoys




- **Application is stationary or slow moving**
- **Geography is open ocean - chiefly off the east coast of the USA and Canada**
- **There is no cellular coverage**
- **Power supply is solar panels**
- **Data is required in real-time, and needs to be bi-directional**
- **Data volume is relatively high**
- **IP-based connection preferred.**

As the customer needs a fairly large amount of data in real-time, and prefers an IP-based connection, we're initially looking at Iridium Certus 100, or Viasat IoT Pro, or - in the near future - Starlink D2C. The latter's power draw could be an issue but the data buoys have several solar panels, so it might be able to cope.

There are no obstacles to line of sight to a satellite for most of these buoys, although the furthest north deployments have some challenges. The customer wanted to be able to prevent rogue transmissions through customizable data limits and alerts; this functionality is baked into the Cloudloop platform that supports both Viasat and Iridium services and hardware.

While the customer wanted the data in real-time, this is because it informs their customers - maritime workers - on weather information, sea currents and even whale presence. It isn't a question of needing a 'live' link to the buoys, so the slightly longer delay of the round trip of data to a GEO satellite wouldn't be an impediment.

So the choice here simply came down to economics: for their data volume, which service would be more affordable? And in this case, it was the Iridium Certus 100 service. From a device perspective, they needed something with a small form factor, space being at a premium within the buoy.

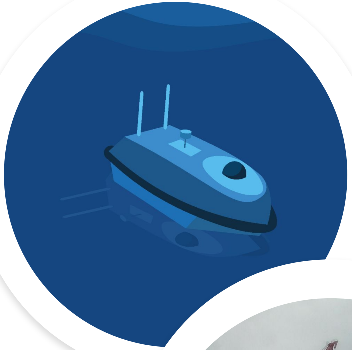
It also needed an external antenna, so we chose the RockREMOTE Mini OEM.

Network: **Iridium**

Service: **Certus 100**

Device: **RockREMOTE Mini OEM**

# Case Study:
# Piloting an Unmanned Surface Vessel BVLOS



- **Application is mobile**
- **Geography is open ocean**
- **There is some cellular coverage when the vessel is close to shore**
- **Power supply is solar panels**
- **Customer needs to be able to assume full remote control of the vessel**
- **Data volumes are high.**

The critical requirement here is the customer needs to be able to pilot the vessel Beyond Visual Line of Sight. This requires a real-time, IP-based connection with high satellite availability and low latency.

Right now there's really only one service we'd recommend for this, and that's Iridium Certus 100. This is because the network is in LEO, so latency is low; it is a fully mature network, so satellite availability and reliability is ironclad. It is a TCP/IP-based connection, with data speeds of 22/88 Kbps.

In terms of the device, we recommended a transceiver that can switch between cellular and satellite networks seamlessly, on a lowest-cost routing basis. The customer didn't have the SWaP challenges of a UAV, so the IP67 rated RockREMOTE Rugged was ideal for this purpose (for UAVs we'd recommend the smaller and lighter RockREMOTE Mini).

When Starlink D2C comes online, this could be another option for the customer to explore, as it will also facilitate real-time connectivity and very low latency. Starlink D2C is not a global service; the model depends on Starlink having commercial relationships with cellular companies, and at the time of writing, has these partnerships in 9 countries.

This particular customer utilizes most of their USVs in the Gulf of Mexico, so as it stands, Starlink wouldn't have the coverage they need - plus the power draw may be an issue. But undoubtedly Starlink will create more partnerships in the coming months and years, and it's one to watch.

Network: **Iridium**

Service: **Certus 100**

Device: **RockREMOTE Rugged**

# Closing Remarks

Choosing the right satellite network for your IoT application is essential to unlocking the potential of your project. The first hurdle to overcome is accepting that you have data constraints, and factoring these into your infrastructure design. Without this, you'll drain batteries faster, congest networks unnecessarily, degrade the service quality - and, in the case of satellite connectivity, you'll spend far more money than you need to.


```
[
    {   "tracker_id": "ABC-12345",
        "gps_timestamp": "2024-02-02 14:00:00 UTC",
        "latitude": 50.877647235226675,
        "longitude": -1.2523121843206868
    },
]
```



**381B08ADEDC5A47F**


153 bytes → 8 bytes

Take this example. In the original message, there is 153 bytes of data, and it's human-readable.
**In the adapted message, there's 8 bytes of data; unreadable by humans but very easy for a machine to unpack.**

If you can get your data into a message-based format, you'll have a more cost- and power-efficient solution, but it's not suitable for all applications.

**Another option for lowering your data transmissions is to leverage edge computing, facilitating reporting by exception and condition-based logging. If your sensors / gateway have this capability, fantastic; if not, it's worth exploring a satellite IoT device that has edge computing capabilities, such as the RockREMOTE or RockBLOCK Sense/Switch.**

Latency and mobility are key influences on your choice of network, with LEO networks having the advantage over GEO networks when low latency and high mobility is a requirement. But if you can manage with a slightly longer round trip delay, and your application is stationary or slow moving, GEO networks are reliable and affordable.

**Above all, please take the opportunity to speak to a satellite IoT expert who can offer you impartial, expert advice on this topic. Look for a service provider who works with multiple satellite networks, so you can be confident they don't have any particular 'skin in the game' where a single constellation is concerned.**


Ground Control

We would of course love to help you solve your remote IoT connectivity challenges, so please get in touch.

- 20 years' experience
- Unbiased network recommendations
- Great airtime rates
- Future-ready IoT insights
- Satellite IoT platform
- Design and build own hardware

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