DISRUPTIVE
TECHNOLOGIES

WHITE PAPER

MAKING IOT SENSOR SOLUTIONS FUTURE-PROOF AT SCALE

Wireless sensor range vs. scalability: Understanding the key trade-offs

Terje Lassen
Product Manager Wireless Communication
Disruptive Technologies AS

Contents

Introduction

Internet of Things, typically defined as modern solutions to collect real-world data at scale, is still in its infancy. There are a vast number of solutions available, with different use cases in mind, and different pros and cons. To deliver on the promise of a true Internet of Things, the complete solution needs to be built with security and scalability at its core. Scalability in this white paper refers to a high density of sensors in a deployment. For example, tens of thousands of sensors in a single building, and millions across a campus.

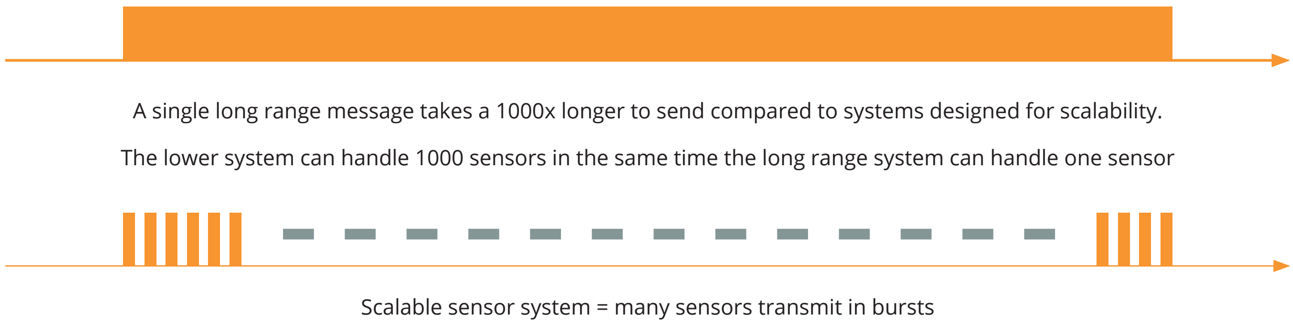
Wiring even a handful of sensors can be costly and limits where sensors can be located. Wireless sensors enable cost-effective and scalable IoT deployments. Before deploying a sensor solution, understand the key tradeoffs between sensor range and scalability.

	SecureDataShot™ (SDS)	Long range solutions (e.g. LoRa)
Wireless range	up to 25 m indoor and up to 1 km outdoor	Kilometers (for few sensors)
Density, number of sensors in a small area	10s of thousands per cloud connector	up to 200, issues reported with 100 sensors per building
Number of gateways	Higher	Lower
Bandwidth efficiency	High	Low to very low
Applications	Best for high data collection, high density applications, such as: • Building automation and predictive maintenance • Temperature monitoring of rooms, refrigerators, drugs, industrial equipment, pipes, etc. • Open/closed monitoring for windows and doors • Service feedback buttons	Best for low data collection, long range applications, such as: • Agriculture monitoring of crops and livestock • City services like lighting and waste removal • Flood monitoring

Current wireless technologies

Today there are only three wireless technologies that can be viewed as true standards: Cellular, WiFi and Bluetooth. All other wireless technologies are proprietary networks with limitations like a single vendor for key parts of the system, limited regional support, etc. The benefit of using a proprietary technology is that it can be tailored to e.g. small wireless sensors, instead of being generic, with support for many different types of communication needs. This paper focuses on these proprietary technologies as a way to achieve scale.

Figure 1: Length of long-range messages vs length of messages for scalable IOT systems



How wireless range works

When deciding which wireless technology to use, the wireless range is a key parameter to consider. At first glance, it seems logical that the more range you can get, the better. The choice is, however, not that simple. There are important trade-offs, and as can be seen from the examples below; range and scalability drive in opposite directions. There are many factors that affect the wireless range. Given the strictly defined rules for RF emission levels, the main practical parameter available to a system designer that affects range is the data rate, i.e. the speed of communication.

The way radio communication reaches further is to “speak slower”. This makes it easier for the receiver to understand the message at longer distance, where naturally the signal is weaker. The downside is that it takes a longer time to send the information. As an example, using a long range wireless system with 1 kilobit per second will use 1000x longer time to get the same message transmitted compared to a Bluetooth device operating at 1 megabit per second. This means that a high-speed receiver can get data from 1000 different sensors in the same time as a long-range receiver can get a single message from one sensor.

From this simple comparison, it is obvious that low data-rates and long-range are very strong limitations on scaling the number of sensors[1]. If the geographical aspect is also put on top, the scaling challenge gets exponentially worse. A 1000x difference in data-rate translates to around 32x the range[2].

Consider the following simple example:

- You have a 1 Mbps system with 10 m range. Assume this system can handle 1000 sensors in an area of $\pi \cdot (10m)^2 = 314\ m^2$
- For comparison, a 1 kbps long-range system can only handle 1 sensor at the same time. With 32x more range, i.e. 320 m radius, that means a single sensor in an area of $\pi \cdot (320\ m)^2 = 322.000\ m^2$

1 Simplified model as high rates use more bandwidth. Generally high rate systems are much more bandwidth efficient compared to long range / low rate systems

2 1000x energy needed, i.e. 30 db. 6 db approx. 2x range line of sight gives 2^5=32x range

This is the simple, physical reason why long-range systems cannot scale to the needs of modern IoT solutions. Consider this result in a practical application in a building. If you have a long-range system that e.g. can cover a building with a single gateway, it will not be able to scale to more than a few 10s, or maybe up to 100+ sensors in the whole building. A sensor solution built for scale will logically require more gateways, but can then easily be deployed to cover 10s of thousands of sensors. This capability is needed to support use cases like temperature monitoring, door/window monitoring, feedback buttons, etc. Once the infrastructure is in place, it is vital that new applications can be added without the need to change or replace the infrastructure (gateways).

Figure: Range vs. scalability for sensors in buildings

Long-range wireless systems are built for applications with very few sensors in a very large area. For use cases in e.g. building automation, where you easily find 100s and even 1000s of sensors in a single building, the higher data-rate on sensors is needed to be able to support the number of sensors. The downside is the shorter range, which means more receivers/ gateways. This is a known trade-off, and why cellular networks have very dense base station deployments in urban areas, with support for many devices and high data-rates, and have low-density base station deployments in rural areas to support only low data rates.

Long range and spread spectrum explained

There is a common misconception that long-range systems, like LoRa, use spread spectrum techniques to achieve high data rates and long range. The simple fact is that spread spectrum does not itself give longer range. Long range is achieved by using low data rates. It is physically not possible to have high data rate and long range, no matter what technology is used. The relation between data rate and range is defined in signal processing theory, and different techniques are used to come as close to the theoretical limit as possible. Spread spectrum is a well-known technique to get closer to the theoretical limit for very low data rates. For higher data rate systems, however, spread spectrum has typically limited value, and drawbacks such as excessive bandwidth usage often make it counterproductive.

In the example of LoRa[3], the LoRa technology supports extremely low data-rates, down to as low as 18 bits per second. This naturally gives very long range performance, but also places very strong limitations on the number of sensors in a wide area.

It has been reported that in practical deployments, LoRa cannot support more than approx. 200 sensors in a wide area. This limitation will typically not be seen during test and piloting, but will become a critical issue in real-world deployments. We recommend you investigate before starting a LoRa implementation.

What happens if my network hits the scaling limit?

A communication system can in many ways be compared to a transportation system. Consider a highway with two lanes in each direction. It can handle a lot of cars, up to a certain point. When this point is reached, you get congestion and the traffic gets stuck, and very few cars come through. The same is the case for a wireless system. If your road, i.e. your radio channel, gets congested, very little data will get through. You can always build a new road in parallel, or in our analogy, use another RF channel, but as long as you do not use the roads efficiently, you will very quickly run into congestion issues again.

As radio spectrum is in its nature shared by everyone, using a wireless sensor technology that does not make efficient use of the spectrum will not only be a problem for the inefficient technology, but for everyone else using the same spectrum! If traffic is stuck, no one gets through, no matter what type of car they use. This is the simple reason why cellular operators invest heavily in radio technologies to improve spectrum efficiency -- to allow more wireless devices to share the limited radio spectrum available.

Disruptive Technologies’ wireless protocol design

Disruptive Technologies have designed extremely small and energy efficient sensors, built to scale to billions of sensors. Due to the very limited energy available in the miniature sensors, the available standard radio technologies (cellular, wifi, Bluetooth) were not a direct fit.

Inspired by cellular network technology, Disruptive Technologies have designed a tailored protocol for miniature sensors called SecureDataShot™ (SDS). SDS provides end-to-end encryption and seamless roaming across base stations, in SDS called Cloud Connectors. The data rate chosen has a range similar to wifi, as the deployment of wifi is well known and proven highly scalable.

The SDS protocol is designed to allow up to one million sensors to operate in a small, geographical area. The SDS protocol is designed for highly efficient radio spectrum usage to enable it to share spectrum with other sensor technologies that also operate with fair spectrum usage.

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3 LoRa is owned by Semtech, and Semtech is the single source vendor for the radio technology used

Conclusion

As shown in this whitepaper, there is a key trade-off between wireless range and scalability.

- Long range solutions, like LoRa, are a good fit for applications that have few sensors in a wide area.
- For applications that need more scalability, both for applications now and for the future, choose systems with efficient bandwidth usage to avoid congestion and system failure.

Radio spectrum is a limited, shared resource, and efficient use has always been the key to successful wireless systems.

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Sensors anywhere. Insights everywhere.

Disruptive Technologies is a rapidly growing innovator in the IoT market and developer of the world's smallest commercial-grade wireless sensors. Our sensing solution based on these mini-sensors simplifies data collection and delivers the data securely to our partners' analytics programs in the cloud.

Leading-edge companies build radically different smart solutions on our platform for Industry 4.0, commercial real estate, retail, food service and safety, and healthcare applications. Together we enable facility managers to maximize space and keep tenants happy, pharmacists to ensure drugs don't spoil, and engineers to protect critical assets. From predictive maintenance to proper refrigeration, we're connecting people and information to deliver Connected Change™.

To learn more, visit www.disruptive-technologies.com

Disruptive Technologies Research AS
Ytrebygdsv. 215, 5258 Blomsterdalen, Norway
500 7th Avenue, New York, NY 10018, USA
Bergen • Oslo • Trondheim • London • Paris • München • New York
+47 57 98 88 55 • sales@disruptive-technologies.com