ACOEM Group

White paper -
Wireless Monitoring
and Predictive Maintenance:
Be smart!

BE SMART

Wireless Monitoring and Predictive Maintenance: Be smart!

EDITORIAL

WIRELESS CONNECTIVITY'S IMPACT ON PREDICTIVE MAINTENANCE – A NEW APPROACH

Wireless technology is an integral element is today's society, and one that is gaining momentum in industry. Wireless capabilities are now being incorporated into industrial machinery, providing lower-cost access to operating and production data.

The introduction of wireless sensors for permanent monitoring and feeding predictive algorithms that automatically warn maintenance teams, is a positive opportunity for industries interested in implementing predictive maintenance programs or enlarging the field of applications that can benefit from them.

Opportunities for greater efficiencies and cost-cutting exist, but only if wireless technology has been mastered to its fullest potential for the required application. Otherwise, the impact of those solutions on Overall Equipment Effectiveness (OEE) and Return on Investment (ROI) could be lower than expected.

Big Data, or the systematic collection of all production data, is not necessarily the most efficient strategy, and may not actually be compatible with the technical limitations of wireless technology.

As a specialist in rotating machinery with more than 30 years' experience, we have deployed large scale wireless vibration monitoring systems in a variety of industries.

We are convinced that wireless predictive maintenance is establishing a new paradigm in meeting industry's expectations.

We wanted to write this white paper to clarify our approach to wireless integration for potential users. We hope it will help them properly define and handle future projects and assist them in deploying functional systems that will meet their expectations.

This white paper was written by the team at ONEPROD with contributions from our technical partner, SEQUANTA, with whom we developed our ONEPROD EAGLE wireless monitoring system.

OneProd

ONEPROD, a brand of ACOEM, provides predictive maintenance solutions including acquisition, processing, analysis and display of data through easy to use and powerful web interfaces freeing up operators to focus on their jobs and decision-making.

SEQUANTA

SEQUANTA designs and develops multipoint and autonomous wireless data acquisition systems to feed analysis software with relevant and accessible data.

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1 PREDICTIVE MAINTENANCE: TOWARDS A CHANGE OF PARADIGM?

FROM BIG DATA TO SMART DATA

On the surface, wireless solutions can appear to be the perfect partner of Big Data – easier to deploy and more affordable, thanks to the lower cost of development for new communication infrastructure and reductions in the price of components (micro controller, batteries, sensors). Until recently, users believed that collecting as much data as possible was necessary to build efficient predictive algorithms.

However, wireless brings new challenges relating to the transfer of data. The data flow of long range and low consumption protocols (LPWAN), the battery lifetime of systems, and even the number of authorised connection points can limit the amount and volume of information that can be collected.

The development of wireless leads to:

1. New data acquisition strategies created by selecting those that are particularly useful for predictive analytics
2. Reducing the volume of data to facilitate its transfer while paying attention to factors that may affect the quality of the information collected.

We are currently switching from massive raw data collection strategies that involve unqualified and post-processed information to a targeted acquisition strategy, based on specific expertise and analysis at the source of the data chain.
The main advantages of this change using wireless solutions are that data processing is focused on relevant information and that results are obtained much faster.

« Trying to collect all data to prevent missing something important is not a good approach given the availability of modern diagnostic methodologies. »

Guillaume Lavaure,
ONEPROD Product Manager.

FROM REAL TIME TO THE RIGHT TIME

How we use wireless data can lead us to believe that wireless solutions can be used continuously in real time – but unfortunately this is not the case. Only wired monitoring systems can provide enough continuous bandwidth to perform real-time monitoring.

Wireless monitoring should be considered as:

1. Periodic: from one to several hundred measurements per day depending on the system
2. Having latency: from a few seconds to several minutes depending on the volume of data on the wireless coverage and available bandwidth.

In most applications, this type of periodic and slightly delayed monitoring is not enough to detect symptoms of faulty behavior. Deeper thinking and the right tools are required to properly define the data acquisition strategy, including:

- Defining a reasonable data measurement periodicity
- Automatic shortening of data measurement periodicity in case of a monitoring indicator status change
- Regularly querying a key indicator and taking a complete set of measurements only if its status changes
- Automatic triggering of measurements at specific times of the operating cycle.

As soon as data correlation is needed between different sensors, it is important that all components of the infrastructure have the same time reference – synchronisation of sensors' timing is crucial.

FROM CLOUD COMPUTING TO EDGE COMPUTING

When implementing a Big Data strategy in which the data merger is set to the upper level of the information system, data that feeds predictive maintenance models is usually managed on a central or cloud server. But, once again, due to the limitations on data flow on industrial wireless networks, a new, more relevant trend is emerging – edge computing.

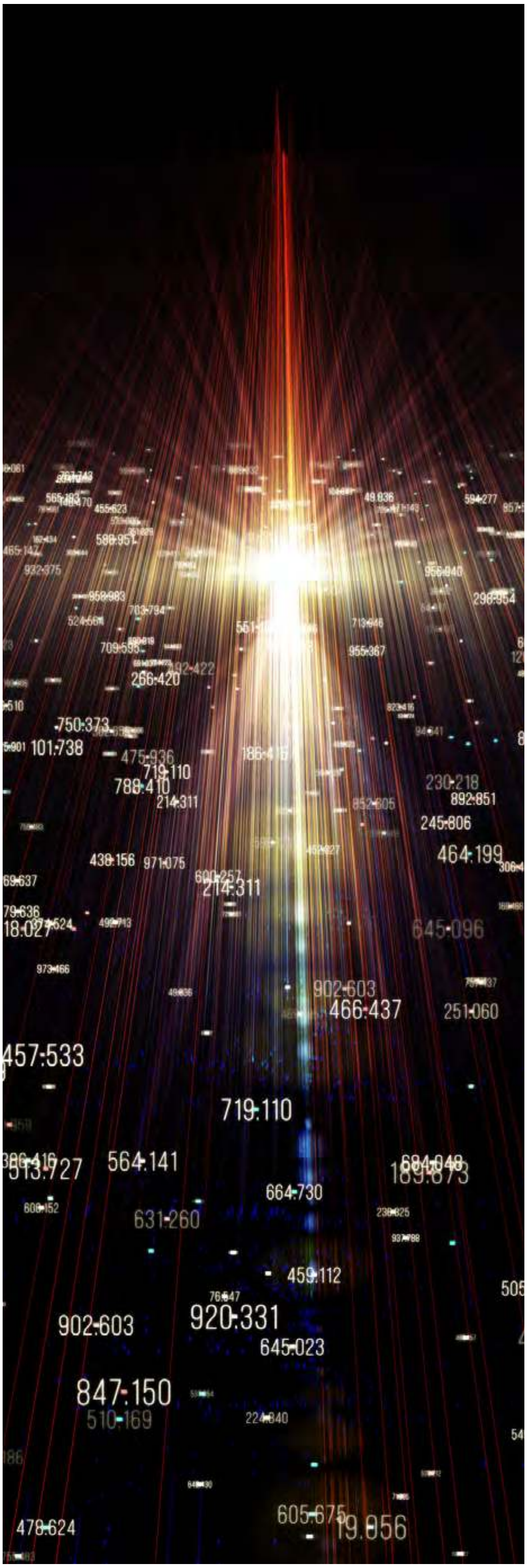
Originating from embedded systems, edge computing is a network architecture which allows data produced by internet of things (IoT) devices to be processed closer to where it is created instead of sending it across long routes to data centres or clouds. Data is processed by the sensor itself or by a local sever instead of being transferred raw to a central server.

Compared by Deloitte* to lean methodology, edge computing is especially efficient in the context of wireless applications as it reduces the bandwidth and accelerates data exchanges.

The development of edge computing doesn't imply the removal of central servers or centralised analysis systems – rather it is the recognition of a new approach to intelligence distribution within different parts of the network. This new approach includes:

- Raw data processing, automatic event detection and actions as close as possible or directly within the sensor itself
- Predictive algorithms, machine learning, automatic generation of tickets and human decision-making on the central server application.

* Source : https://www2.deloitte.com/insights/us/en/focus/industry-4-0/using-predictive-technologies-for-asset-maintenance.html



TOWARDS GREEN DIGITALISATION

The ACOEM group's mission is to help companies reduce their environmental impact so it is important that we mention the environmental cost of data storage.

Collecting and storing huge quantities of data but only using a small proportion of it, is not only inefficient from a maintenance operations perspective, but it's also bad for the environment.

All data collected is hosted on servers that run 24/7 and need to be permanently cooled. According to the European Commission, data centres operating across the EU consumed approximately 56 billion kilowatts in 2008, and that figure could reach 104 billion in 2020*. Worldwide, that equates to potentially 12% of our total global energy production being ingested by our digital ecosystem in 2020**.

If we want to limit the energy consumption of digital technologies, we have to develop a green approach to data handling – only collecting useful information and storing it in the lightest form possible. Hopefully, power and communication limitations of the wireless platform will push us to optimise the ratio between weight and added value of the data transiting on the network.

To do so, we have two choices:

- Use artificial intelligence to select useful data rather than massively collect data to improve algorithms
- Place the intelligence within the sensors to maximise added value in a minimum of octets, even before the data is pushed on to the network.

In our opinion, edge computing is essential for any efficient predictive maintenance strategy to succeed and it's currently the best option available for developing powerful and lasting wireless solutions.

2

WHAT ROLE SHOULD WIRELESS PLAY IN PREDICTIVE MAINTENANCE?

WIRELESS: FROM WARNING TO DIAGNOSTIC

The objective of predictive maintenance is to maximise Overall Equipment Effectiveness (OEE) at the lowest possible cost. It does so by acting at the optimal time, when the asset has worked as long as possible without the incidence of a fault severe enough to stop the machine.
Whether monitoring is performed with a wired or wireless system, the root questions remain the same:

- Which faults do we want to detect?
- How do these faults reflect on the measured data?
- How quickly might they evolve?
- At what point should it trigger an action?
- What type of action should be triggered?

Depending on the answers to these questions, the data required may be different:

- Warning data: first level information (positive or negative) linked or not to an evolution trend
- Diagnostic data: detailed second level analysis (identifying the nature of the problem and its severity)

The further you want to go in terms of analysis, the more accurate and comprehensive the information needs to be. It moves from scalar data (e.g. overall level of vibration velocity, temperature, etc.) at the first level, to rich dynamic signals (like a vibration spectrum or time waveform that contains several thousands of values) at the second level of analysis. The size of the information varies from a few octets at one level to mega octets at the next. The analysis strategy is also quite different. At the first level, simple data is aggregated and trended, and at the second, precise information that will inform the right decision from a larger set of rich, complex data can be pinpointed.

Today, most wireless solutions only deliver first level information. They allow for periodic monitoring but are reduced to warning level and rely on a potential remote artificial intelligence from a third system to extract a predictive model from basic information.
Using partially distributed intelligence, ONEPROD's EAGLE solution wirelessly delivers two levels of information. In this first important step towards a comprehensive wireless monitoring system, EAGLE exceeds expectations in terms of ROI, both in the short term (optimising human maintenance actions and their duration), and in the mid-term (determining predictive systems).
Our built-in software extracts relevant indicator sets from complex time waveforms. The ability to analyse and split the information at the source provides added value, allowing it to be sent on the network in a pre-digested, much lighter form.
The more advanced the built-in algorithms, the easier it is to mitigate the wireless system's power/data transfer rate limitations, bringing performance closer to that of a wired monitoring system. The next step we are considering is to go further in terms of built-in and distributed intelligence and introduce edge computing automatic diagnostics. Wireless capacity will then be powerful enough to meet the needs of a larger number of applications.

« We already possess four years' experience in developing automatic diagnostic algorithms – we know they are reliable »

Patrick Labeyrie – ONEPROD France Business Director

WIRELESS TO COMPLEMENT EXISTING SYSTEMS

The technical and financial advantages of wireless systems are undeniable. With the introduction of wireless technology, it's now possible to not only monitor mobile assets in difficult to access or hazardous locations, but also to reduce the costs associated with installation and maintenance of the monitoring infrastructure itself. For these reasons, wireless use is becoming increasingly common.

Despite the apparent benefits, wireless systems need to be evaluated in context and the advantages often depend on the application. For example, they cannot be used to perform real-time vibration monitoring – often required on the most critical equipment or machines – especially when faults can potentially lead to failures within a few hours.

On a large scale industrial site, wireless systems aren't designed to replace wired systems but rather to complement them. Wireless implementation is a significant step forward for information transparency on the full production chain. Vibration monitoring can now extend to machines which, for cost or accessibility reasons, were not previously monitored.

Understanding the current capabilities and limitations of different solutions available is an important precursor to building a smart and scalable predictive maintenance deployment strategy. The benefits of mixing different solutions arise from establishing an expert methodology – picking the right information, in the right place, at the right time. This approach has become easier with the development of extremely powerful analysis algorithms, able to reproduce human expert behavior to manage vibration data.

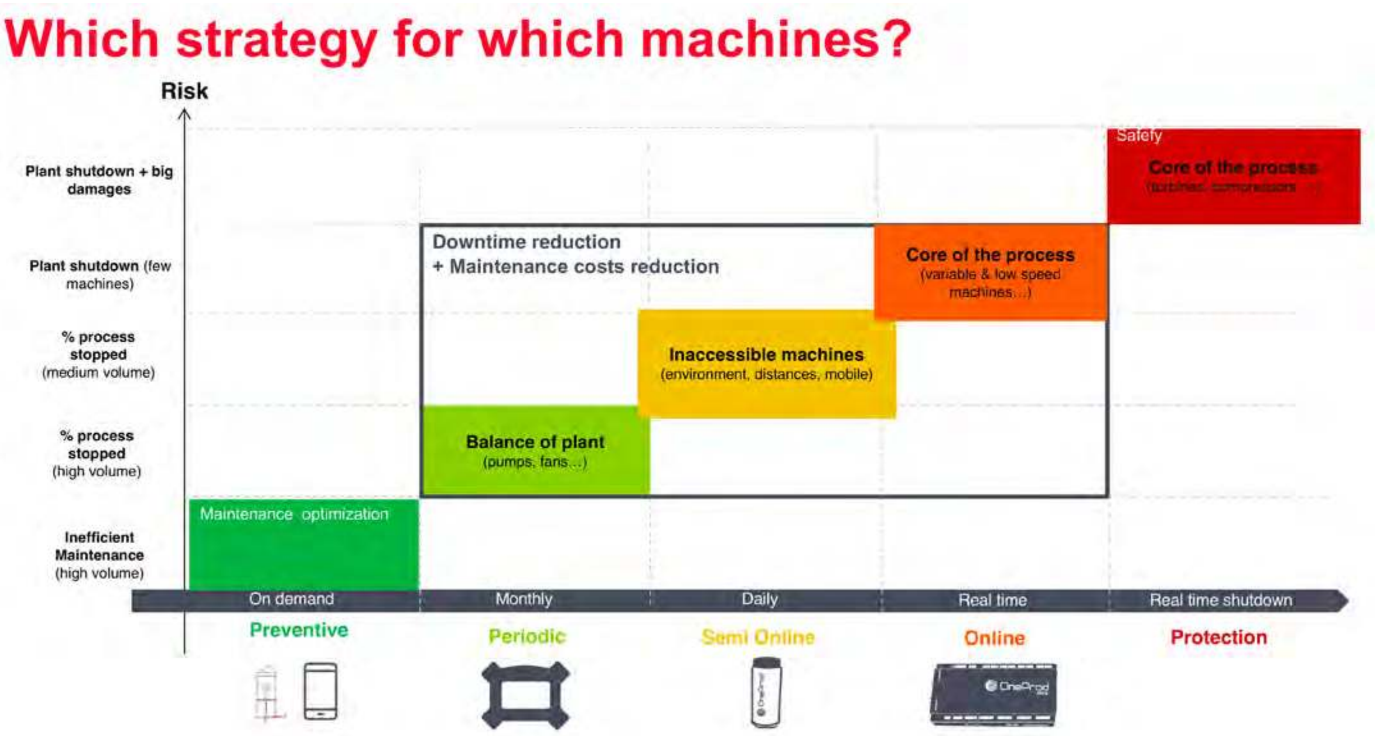
COMPREHENSIVE STRATEGY SOLUTIONS

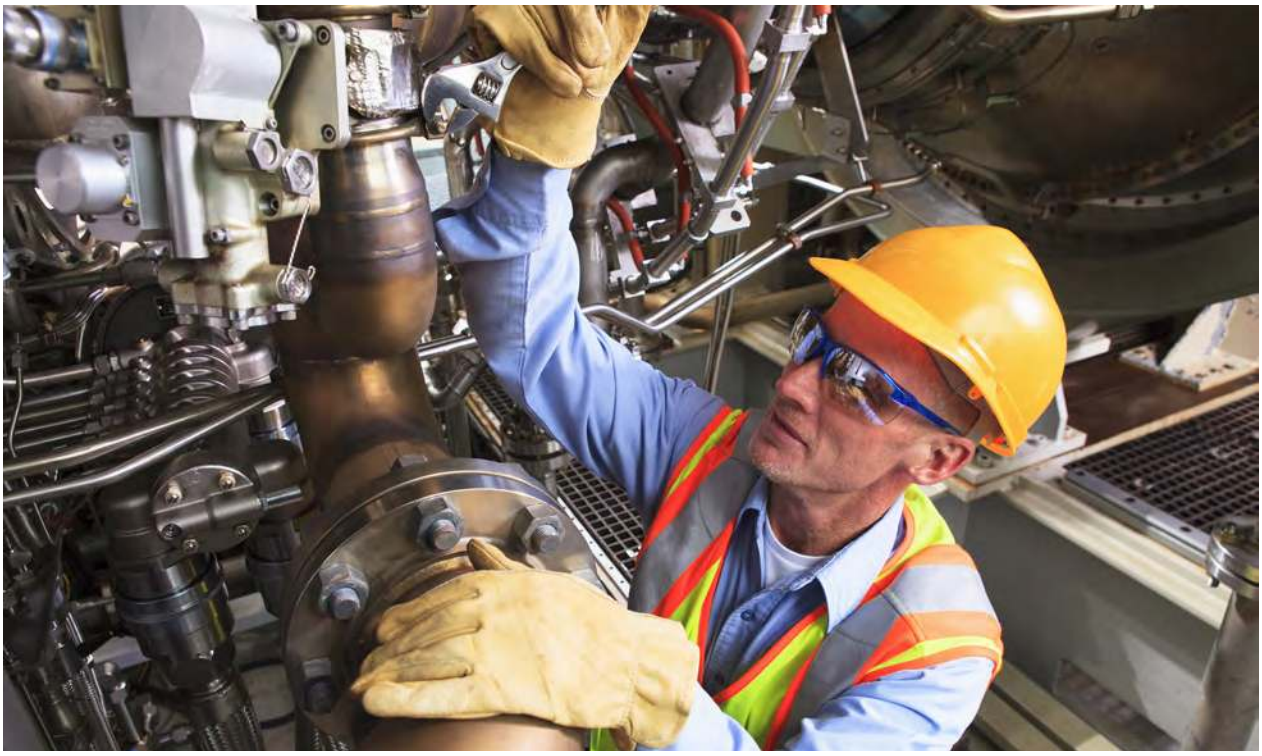
In a multi-technical predictive maintenance strategy, the followed combinations should be considered:

- Wired systems such as the ONEPROD MVX, for the online and real-time monitoring components of the most critical machinery
- Permanently installed wireless systems such as the ONEPROD EAGLE, for remote automatic and periodic acquisition (one to several sets of data per day) for warning and diagnostic data
- Wireless mobile systems (such the ONEPROD FALCON) for in-depth diagnostics, performed by an operator directly on the machine to create monitoring alerts.

ONEPROD's three solutions ensure that data acquisition as well as overall resource allocation strategy are more efficient and contribute to improved maintenance performance including:

- Warning and visualisation of defects at an early stage
- Remote and accurate analysis of the symptoms and recommended maintenance before the dispatch of an operator
- Better management of resources (monitoring automisation, limitation of maintenance actions and displacements, allowing an expert user to analyse a machine's condition from multiple sites remotely).


Which strategy for which machines?
Risk
Plant shutdown + big damages
Plant shutdown (few machines)
% process stopped (medium volume)
% process stopped (high volume)
Inefficient Maintenance (high volume)
Safety
Core of the process
Downtime reduction
+ Maintenance costs reduction
Core of the process
(variable & low speed machines...)
Inaccessible machines
(environment, distances, mobile)
Balance of plant
(pumps, fans...)
Maintenance optimization
On demand
Monthly
Daily
Real time
Real time shutdown
Preventive
Periodic
Semi Online
Online
Protection



3 WIRELESS PREDICTIVE MAINTENANCE: HOW TO DEFINE YOUR SPECIFICATIONS?

KEEP IN MIND THE SPECIFICS OF WIRELESS TECHNOLOGY IN INDUSTRIAL ENVIRONMENTS

We all appreciate how valuable wireless connectivity has become in our day-to-day communications. Why would deploying wireless systems in an industrial environment be difficult? After all, we use wireless to connect everywhere in our daily life.
This feeling subconsciously creates a somewhat unfounded sense of security or comfort when we first approach the idea of integrating wireless into industrial projects. It may mask obvious limitations of the technology, which we encounter every day when our smartphone's battery dies too quickly, or that important SMS doesn't reach its intended recipient.

Those limits become even more apparent when identifying more difficult requirements in industrial environments, including:

- Sensors are regularly installed in harsh environments (humidity, dust, heat, chemical projections, explosives). They must be certified according to applicable standards (IP, ATEX etc.).
- Sensors can't be recharged everyday – they need to be powered by a battery with a life that spans several years. Battery life needs to be accurately estimated, taking into account the sensor-designated activity and environment.
- Wireless waves must travel over ranges of several hundred metres and within an environment that may include obstacles like machines and buildings. Yet somehow, we expect it to be fully operational at all times. A sufficient number of relay antennas must be carefully located and the communication protocol needs to be highly reliable to prevent interferences.
- All sensors must be capable of retrieving information and directing it to the central server at the desired time and with the required reactivity. The bandwidth allocated to each must be guaranteed.

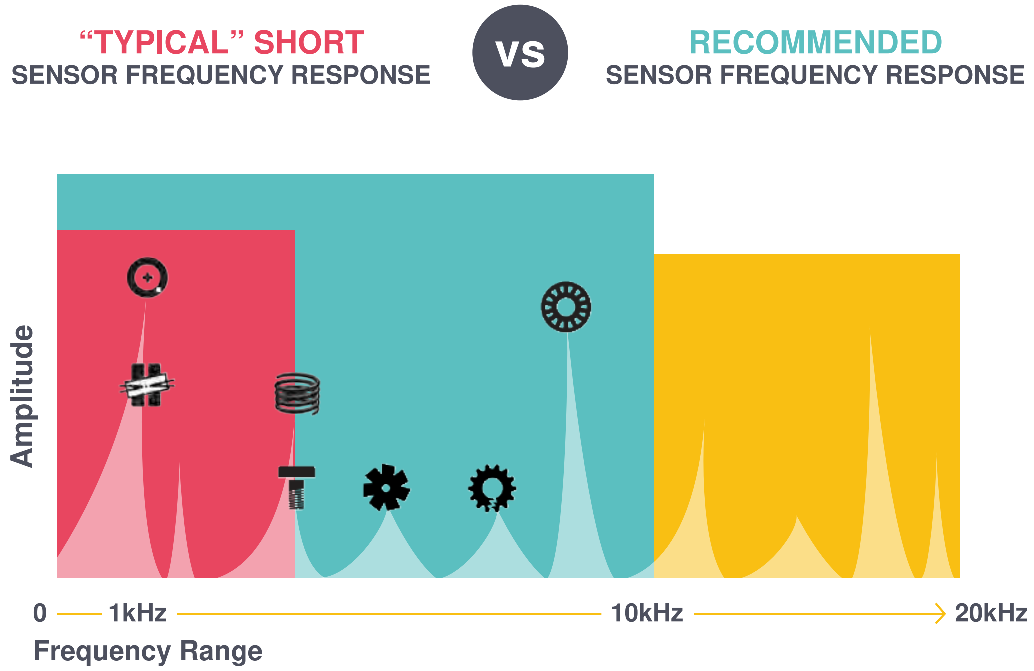
SELECT THE RIGHT SENSOR

All good diagnostics start with reliable information, no matter the level of detail and complexity. Which brings us to the question of the measurement capabilities and accuracy of the sensing equipment used.

For example, vibration analysis sensors that are considered to be performing well metrologically work in high frequencies (10,000 Hz minimum) to cover the most common faults of rotating machinery, including bearing defects.

Most wireless vibration monitoring systems on the market today rely on cheap, smaller sensors, which aren't able to measure frequencies that high and present inferior metrological performance.

By focusing on the "wireless" characteristics of those systems and neglecting the "sensor" component, there is an inherent risk. By ignoring metrological performance of a wireless solution, the ability to monitor all components of your machinery (such as ball/roller bearings) is significantly diminished. It can also have a detrimental impact on how fast the system can detect a fault presence (or even whether it detects it at all) and may cause it to send false warnings and alarms to users.



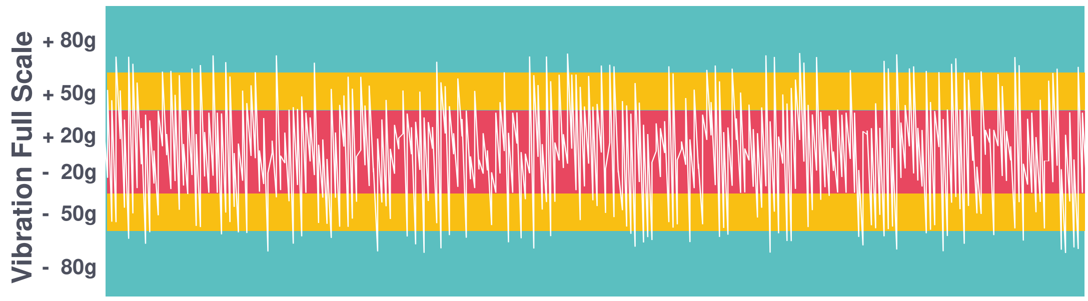
The figure above shows that entry level sensors are limited to the monitoring of the dynamic behavior of rotating machinery (unbalance, misalignment) due to the range of frequencies they can actually measure (frequency bandwidth). They do not allow for detecting and assessing the severity of faults occurring in the high frequency domain (shocks, bearings, gears...).

Types of Machines

- Small electric motors
- Small fans

- Gearboxes
- Pumps
- Compressors

- Large Compressors
- Crushers



This value can be depending on the environment and installation.

Entry level accelerometers are not suitable for the monitoring of numbers of industrial rotating assets. Indeed, the vibration ranges (dynamics) they can work with are often narrow, and sensors can quickly reach their performance limit on machines generating high amplitude vibration, or where abnormal shocks resulting from mechanical damages can occur. There is a risk that the measurement won't be able to be used at all.

UNDERSTANDING BATTERY-LIFE CHALLENGES

With wireless technology, the question of battery life is crucial. It depends on the sensor itself, its environment, type of usage and activity (network connection, acquisition and data processing, data transfer, wireless range and data transfer rate).
The battery will only operate at an optimum level if good choices are made early and if compromises on the data volume transferred on the network are undertaken.
If energy harvesting technology allows sensors collecting basic information to be totally autonomous, they won't be suitable for more power-consuming applications due to the type of measurement and data processing performed. Most wireless solutions today are battery powered. For a wireless sensor's battery to last several years, it needs to have sufficient battery capacity that won't be significantly impacted by environmental conditions like excessively high or low temperatures. Essentially the sensor needs to consume as little energy as possible. This is where we enter the world of wireless networks and communication protocols.
For vibration diagnostics, a high-speed 4G wireless network allows complex time waveforms to be collected but only grants a limited battery life. Low-bandwidth wireless solutions for devices with low-bit rates over long ranges offer a better battery life but can only collect basic information (a few octets).
There is however a third option, a wireless network based on the IEEE 802.15.4e protocol that offers a compromise between data transfer rate and energy consumption. It minimises the power needed for tasks other than data transfer (acquisition, processing, network connection). This is the wireless protocol we selected for our ONEPROD EAGLE wireless system in partnership with SEQUANTA.
Even with the best technical choices, one has to accept the fact that there will be reduced periodicity to ensure a sufficient battery life with reliable and good quality data when collecting more qualified, targeted information as compared to using a wired network.

« We have optimised our protocol so that ONEPROD can transfer rich and complex information while offering good battery life and reliability that meets business application needs »

Guillaume Chelius
SEQUANTA CEO

DEFINING REQUIREMENTS IN TERMS OF SERVICE CONTINUITY

No industrialist would even consider deploying a wired network without asking for guarantees in terms of service continuity and reliability.
Does this standard also apply to wireless networks? Radio support, by definition, is less stable and highly dependent on the environment of propagations of the radio waves. Reflection or diffraction phenomena can weaken the signal, and other networks or electronic devices can generate interferences. As a consequence, radio networks often suffer from micro-cuts that can impact the reliability of the wireless system.
For a wireless system to reach its maximum capability, it must be correctly deployed. The choice and number of wireless emitters as well as their location are crucial.
In addition, as explained previously, data acquisition is more targeted with a wireless system than with a wired system. Data collected is a scarce resource – for instance, it cannot be lost without affecting the

quality of the vibration monitoring. What happens if the radio link breaks when the sensor should have been connected, or if the communication fails during the data transmission phase?

At best, the data will be transferred with a short delay. But it is also possible that the sensor will lose its communication slot (and this is one measurement that is shorter/smaller than expected) or that data will never reach its destination (the measurement was completed in time but was definitely lost).

In some applications, data loss can be considered as a fair risk to take, but if so, is the data acquisition strategy really well optimised? For all other cases, guarantees regarding the robustness of the network over time are needed. With the ONEPROD EAGLE system, those guarantees are provided by the reliability of the communication protocol used. It relies specifically on the Frequency Time Division Multiple Access (FTDMA) principle to share the communication frequencies and the time of activity between the different sensors to avoid disturbances due to interferences between sensors or with other networks. The ONEPROD EAGLE system also allows the components and radio link status to be retrieved in real time. Data security is ensured by the acknowledgment of data packets at each radio hop. Finally, data is timestamped and all network components are synchronised with a real-time, high accuracy network clock, giving a common timeline to all network components.

THINKING ABOUT NETWORK ARCHITECTURE

How can you get quality information quickly when your network is intrinsically limited in terms of bandwidth? The answer comes down to three words: scheduling, topology and processing.

When installing multiple sensors, it is obvious that if all of them try to send their data at the same time, the network will quickly get jammed. But if you program the measurements using a well-organised schedule with time slots that don't overlap each other, the speed of communication will be much faster. Scheduling is a MUST in any wireless application. It's is easy to set up and apply when measurements are not streamed continuously but taken periodically.

In a meshed network which includes sensors, wireless repeaters and gateways (making the link between the wireless systems and the IP network) – like that used by our EAGLE system – it is possible to optimise the topology to maximise the bandwidth assigned to each sensor (maximum number of sensors per repeater, maximum number of hops between the sensor and the gateway etc.).

It is also possible to think of a full wireless solution using broadband communication (like Wi-Fi), between the gateway (permanently connected to a source of power supply) and the central server. Last but not least, the physical installation of the network should be carefully prepared and realised. For the most complex cases, field testing should be mandatory.

SCHEDULING

TOPOLOGY

PROCESSING

Example of topology of a vibration monitoring installation in a cement plant at Siam Cement Groupe (SGC), Thailand.
White: gateway - Blue: wireless repeater -
Black: triaxial vibration and temperature sensor.

SYNTHESIS

TO GUARANTEE THE SUCCESS OF YOUR INDUSTRY 4.0 PROJECT AND AVOID IT BECOMING A COSTLY EXPERIMENT, HERE ARE A FEW QUESTIONS TO ASK YOURSELF WHEN SELECTING YOUR WIRELESS SOLUTION:

1. Which of my assets would benefit from the installation of permanent wireless monitoring?

- How critical is the machine?
- Have you considered periodic monitoring through manual data collection?
- What is the degradation process of your machine?
- Will one or few measurements per day be enough or do you need to put real-time monitoring in place?

2. Does my proposed wireless solution allow me to monitor my machine correctly without generating false alarms?

- Are the sensor dynamics (full-scale) sufficient to avoid saturation that would render the measurement data unusable?
- Is the frequency bandwidth wide enough to cover common faults on rotating machines (unbalanced, misalignment, looseness, bearings, gears etc.)?
- Does the solution have the capability to manage variable operating conditions (speed, load etc.)?
- Is the solution able to manage slow speed rotating components?

3. What is the system's diagnostic capability in case an alarm occurs?

- Can you recognise and avoid false alarms?
- Can you establish a diagnostic and identify the root cause of the alarm?
- Can you quantify the criticality of a defect and deduce the related corrective actions to be taken?

4. Which actions must be carried out when an alarm occurs?

- Analysis by an external service provider
- Analysis by internal resources
- What data do you expect to capture with the wireless system?
- Can the monitoring system send the necessary information to my maintenance management applications?

5. How sustainable is my wireless solution and how can I integrate it with my existing IT infrastructure?

- Standard industrial protocol
- Secured protocol
- Interference with other systems
- Maintainability
- Which industrial references / guarantees does the wireless solution offer?

6. What is the overall cost of Operations & Maintenance of your wireless monitoring system?

- Expected battery life span and frequency of required battery replacement
- Cost of the spare batteries and labour required
- Can the batteries be replaced by your own team?
- How robust are the sensors and what are their expected life spans in an aggressive industrial environment (heat, humidity, dust, corrosion etc.)?

7. What kind of support will I be offered by the service provider?

- Assistance with hardware installation and commissioning of the monitoring equipment
- Assistance with the use of the system
- After-sales support

› Learn more about ONEPROD's EAGLE wireless monitoring and diagnostic solution

SOURCES

ACOEM Patent: US 9,913,006 POWER-EFFICIENT DATA-LOAD-EFFICIENT METHOD OF WIRELESSLY MONITORING MACHINES
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*Source : http://www.lemonde.fr/planete/article/2013/07/01/les-centres-de-donnees-informatiques-gros-consommateurs-d-energie_3439768_3244.html#4U8ZA9Hw31wiIomk.99

** Source : https://www.lebigdata.fr/big-data-bitcoin-catastrophe-environnement

About ACOEM Group

Reduce your environmental impact

In today's fast-moving world, the environment is increasingly impacted. The ACOEM Group is committed to sustainable development and helping companies and public authorities limit their environmental impact by offering products and services that:

- Prevent and control air, noise and vibration pollution
- Increase the productivity and reliability of industrial machinery
- Contribute to the development of effective, robust & noiseless products
- Protect soldiers, sites and vehicles in military operations.

Across the world, ACOEM's 670 employees innovate in the measurement, analysis and control of all environmental parameters through the 01dB, ECOTECH, ONEPROD, FIXTURLASER, MEAX and METRAVIB brands.

For more information visit acoemgroup.com

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