Edge processing enabling Condition Monitoring and Predictive Maintenance: quick start for end-to-end architecture based on wired Smart Sensor Nodes and Gateway

Value proposition and benefits

ST provides a comprehensive framework for users to develop and test Condition Monitoring and Predictive Maintenance solutions based on vibration and environmental data streams.

We provide users with a quick start environment for Proof of Concept of industrial solutions connecting multiple sensor nodes to a central data lake such as a Cloud service.

Critical vibration data is processed locally on STEVAL-BFA001V1B sensor nodes by an STM32 microcontroller, which outputs frequency and time domain data, as well as temperature, pressure and humidity data. The data from up to four sensor nodes with IO-Link transceivers (IO-Link stack not included) is then routed through an IO-Link master to an Edge gateway node (STM32MP157C-DK2 Discovery Kit), where all the data is consolidated and further processed by server-based or cloud-based elaboration and connectivity software.

In order to expose the potential of a cloud-based solution, we provide a Predictive Maintenance Dashboard application from which Edge gateway nodes running the AWS IoT Greengrass service and AWS IoT core can be provisioned, so that condition monitoring sensor data can be plotted and triggers can be configured as part of your end-to-end Predictive Maintenance solution.

Features

- Vibration monitoring data in the form of vibration speed (RMS), peak acceleration, and FFTs performed by STM32 core on data acquired from ST industrial accelerometer.
- Temperature, humidity and pressure data from ST environmental sensors.
- Condition monitoring example demonstrating Edge node processing in communication with a Cloud application via a secure gateway.
- End-to-end communication framework allowing Condition Monitoring platform to develop into a Predictive Maintenance solution.
- Further processing potential on Edge node with AWS IoT Greengrass and Lambda functions.
- Cloud Dashboard to register and provision the devices, configure a gateway for Edge processing, assign a gateway to a group of devices, analyze real time and historical data, and set thresholds to trigger alerts for particular equipment conditions.
- Free usage terms for a limited number of sensors and gateways, and for a limited time, as part of the DSH-PREDMNT Cloud application user license agreement.
- Based on STM32Cube and STM32OpenSTLinux expansion packages.
- Serverless deployment of the Dashboard application in user account through Cloud Formation tool.
Description

The Predictive Maintenance Platform (PMP) is a condition monitoring application for the operating conditions of industrial equipment.

All manufacturing equipment with moving parts are subject to degradation which require servicing or component replacement, but traditional maintenance approaches based on set schedules ignore actual equipment condition. In Condition-based monitoring, maintenance is instead scheduled according to the estimated condition of the machine from inspection or from sensor data.

Predictive Maintenance builds on condition monitoring by feeding sensor data into dynamic predictive models for failure modes in an attempt to foresee maintenance requirements as far into the future as can be deemed practical. This can translate into more efficient maintenance planning, less machine down time and longer operating life through investment in system intelligence and other ERP data like equipment life cycle.

The process of evolving from Condition Monitoring to Predictive Maintenance begins with establishing information criteria and building appropriate systems to sense and deliver the data, followed by more intricate phases involving the optimization of thresholds through experience and historical data, and finally the implementation of predictive models able to provide accurate forecasts of the future condition of manufacturing equipment.

**Figure 1. Pathway from Condition Monitoring to Predictive Maintenance**

**Condition monitoring & Predictive Maintenance**

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<td>Reaching Leading Edge: remaining life computation</td>
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<td>3 Events Detection and Classification triggered by failure thresholds</td>
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<td>2 Condition Monitoring</td>
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Time and frequency analyses of vibration data is especially useful for the identification of anomalies. Different analytical techniques can be used, which can include deep learning and AI technologies.

With respect to Figure 1, this solution is designed to get users to step three, in order to gain familiarity with the environment and equipment in which vibration or environmental analysis may be performed.

The architecture we propose is based on an STEVAL-IDP004V1 master board and up to four STEVAL-BFA001V1B smart sensor nodes, which export the following condition monitoring data over a serial protocol:

- environmental pressure, humidity, and temperature data
- time and frequency domain vibration data from the embedded accelerometer, processed by STM32F4 microcontroller
Figure 2. Condition monitoring and Edge to Cloud: from sensors to gateway to cloud dashboard

The Edge node collects environmental data and FFT data from accelerometers processed by the STEVAL-BFA001V1B kit, which is then sent via MQTT over Ethernet or Wi-Fi to the DSH-PREDMNT dashboard based on the AWS infrastructure.

The data is collected and further processed in an Edge gateway consisting of an STM32MP157C-DK2 kit running X-LINUX-PREDMNT software, which includes the AWS IoT Greengrass service.

The DSH-PREDMNT dashboard completes the journey with a web-based tool to manage device provisioning, configuration, data injection and analysis, and simple thresholds for anomaly detection from a centralized Cloud service.

The AWS IoT Greengrass Edge Computing service allows local computation of Lambda functions on Edge gateway nodes with the same logic available on the Cloud to ensure continuity even when connection to the Cloud is unavailable; shadow devices on the Cloud are automatically synchronized with the Edge nodes as soon as connection is reestablished.
1 Hardware components, software and core products of Predictive Maintenance solution

Each hardware can be used in different ways respect what is here described. You can access the www.st.com related page to get more information.
For example, the smart sensor node can be used in a standalone configuration with his firmware to be integrated in other use cases.
As well the Smart Sensor Node and the Master offer the capabilities to be integrated with other gateways and concentrators.

Table 1. Key components of Predictive Maintenance solution

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<tr>
<th>Component</th>
<th>Hardware</th>
<th>Firmware / Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Sensor Node</td>
<td>STEVAL-BFA001V1B</td>
<td>STSW-BFA001V1</td>
</tr>
<tr>
<td>Master</td>
<td>STEVAL-IDP004V1</td>
<td>STSW-IDP4PREDMNT</td>
</tr>
<tr>
<td>Gateway</td>
<td>STM32MP157C-DK2</td>
<td>X-LINUX-PREDMNT</td>
</tr>
<tr>
<td>DASHBOARD</td>
<td></td>
<td>DSH-PREDMNT</td>
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1.1 STEVAL-BFA001V1B with STSW-BFA001V1

The STEVAL-BFA001V1B is an industrial reference design kit designed for condition monitoring (CM) and predictive maintenance (PdM).
The hardware consists of an industrial sensor board, an adapter for the ST-LINK/V2-1 programming and debugging tool (STEVAL-UKI001V1), a 0.050” 10-pin flat cable, a 4-pole cable mount connector plug with male contacts and an M12 female connector with a 2 m cable. The firmware package STSW-BFA001V1 includes dedicated algorithms for advanced time and frequency domain signal processing and analysis of the 3D digital accelerometer with 3 kHz flat bandwidth.
The firmware runs on the high performance STM32F469AI, ARM® Cortex®-M4, 32-bit microcontroller and the sensor data analysis results are sent via wired connectivity based on IO-Link device transceiver (IO-Link stack protocol not included).
A dedicated version for the solution is provided in binary format.
Main products:
- 32-bit ARM® Cortex®-M4 core for signal processing and analysis (STM32F469AI)
  - Precompiled binary: STSW-BFA1PREDMNT.zip based on STM32Cube
- iNEMO 6DoF (ISM330DLC)
- Absolute digital pressure sensor (LPS22HB)
- Relative humidity and temperature sensors (HTS221)
- Digital microphone sensors (MP34DT05-A)
1.2 STEVAL-IDP004V1/STEVAL-IDP004V2 IO-Link master with STSW-IDP4PREDMNT

The STEVAL-IDP004V1/STEVAL-IDP004V2 IO-Link master evaluation board with STM32 microcontroller has four L6360 ICs. Communication with the ICs is via I²C in master mode and is managed by the STM32F205RB MCU. Each L6360 has its own address and shares the bus with the other devices.

The IO-Link master evaluation board is developed to create a multi-port master based on serial asynchronous communication to support the IO-Link protocol. Each node is equipped with an industrial M12 connector (as required by the standard) for connection with a single slave node using a 20 meter cable. Beyond the IO-Link connection, the board includes RS-485 bus, CAN bus and USB hardware interfaces.

The layout is designed to meet the requirements for IEC61000-4-2/4/5 for the industrial sector.

The STSW-IDP4PREDMNT firmware implements asynchronous serial communication to manage data exchange between sensor nodes and edge nodes. Both communication protocols have been customized to better fit the application needs, no standardized protocol (like IO-Link stack) has been included.

A set of commands have been implemented, to enable the communication between gateway and smart sensor node, to transfer environmental data and vibration data (time domain and frequency domain).

This binary for master node is compatible with STEVAL-IDP004V1 as well as STEVAL-IDP004V2.

Main products:
- 4x L6360 IO-Link master devices
- RS-485 serial interface
- CAN serial interface
- USB interface
- DC-DC converter
- Precompiled binary: STSW-IDP4PREDMNT.zip based on STM32Cube
The STM32MP157A-DK1 and STM32MP157C-DK2 Discovery kits leverage the capabilities of STM32MP1 Series microprocessors to allow users to develop applications using STM32 MPU OpenSTLinux Distribution software for the main processor and STM32CubeMP1 software for the co-processor.

They include an ST-LINK embedded debug tool, LEDs, push buttons, one Ethernet 1-Gbps connector, one USB Type-C OTG connector, four USB Type-A Host connectors, an HDMI transceiver, a stereo headset jack with analog microphone, and a microSD connector. To expand the functionality of the STM32MP157A-DK1 and STM32MP157C-DK2 Discovery kits, two GPIO expansion connectors are also available for ARDUINO and Raspberry Pi shields. The STM32MP157C-DK2 Discovery kit includes an LCD display with a touch panel, as well as Wi-Fi and Bluetooth Low Energy connectivity.

X-LINUX-PREDMNT is an STM32 MPU OpenSTLinux Expansion Pack used in conjunction with WIREST-SDK and EDGEST-SDK implements edge processing functionality between wire-connected sensor nodes and cloud services. The overall PMP setup involves registering sensor devices through a dashboard, configuring an STM32MP1 Series microprocessor as an Edge gateway and connecting with a cloud service provider.

Processed environmental and inertial data can be sent to the IoT cloud, viewed on the dashboard, and analyzed to detect conditions which may indicate the need for maintenance intervention.

The package includes the AWS IoT Greengrass Edge Computing service to allow local processing of sensor data through Lambda functions on the Edge gateway, even in absence of cloud connectivity. Data synchronization when the cloud becomes reachable again is handled automatically.

Main products:
- STM32MP157 Arm®-based dual Cortex®-A7 32 bits + Cortex®-M4 32 bits MPU in TFBGA361 package
- ST PMIC STPMIC1
- 4-Gbit DDR3L, 16 bits, 533 MHz
- 1-Gbps Ethernet (RGMII) compliant with IEEE-802.3ab
The Predictive Maintenance Dashboard is a cloud application based on AWS services. It provides a highly functional and intuitive interface that is tailored for the collection, visualization and analysis of condition monitoring data from motion and acoustic vibration sensing elements, as well as temperature and other environmental data. You can use the dashboard to plot and graph real-time and historical data, monitor critical operating conditions such as running temperature, and set thresholds for automatic warnings when key parameters exceed acceptable limits.

The cloud package can receive and process data streamed directly from compatible ST sensor nodes with real-time data pre-processing capabilities such as Fast Fourier Transforms (FFT), and also provides SDKs for the AWS IoT Greengrass service to interface with edge gateways managing compatible ST devices capable of bulk data pre-processing and storage. As the dashboard runs on a third-party cloud storage service provider, the number of ST IoT sensor nodes you can connect on a free trial basis is limited to five, for a maximum duration of 6 months. You may also receive warnings if your data throughput approaches certain levels, but these may be negotiated if you contact our sales office to discuss your specific requirements.

Key Features

- Device and edge registration and configuration
- Data visualization
- Asset health monitoring
- Position and status overview map of tracking system
- Application framework based on Amazon Web Services
- Data volume limits:
  - Automatic user notification
  - Trial basis duration: 6 months
  - Max number of devices: 5
- User data segregation
2 Solution resources

Documentation resources:

• X-LINUX-PREDMNT User Manual (UM2639): How to use the Edge Processing Application for Predictive Maintenance
• DSH-PREDMNT Quick Start Guide: Predictive Maintenance Cloud Application

<table>
<thead>
<tr>
<th>Order code</th>
<th>Description</th>
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<tr>
<td>STEVAL-BFA001V1B</td>
<td>Predictive maintenance kit with sensors and IO-Link capability</td>
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<tr>
<td>STEVAL-IDP004V1 / V2</td>
<td>IO-Link master multi-port evaluation board</td>
</tr>
<tr>
<td>STM32MP157C-DK2</td>
<td>Discovery kit with STM32MP157C MPU</td>
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<tr>
<th>Software Code</th>
<th>Distribution</th>
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<tr>
<td>STSW-BFA1PREDMNT.zip</td>
<td>Binary</td>
</tr>
<tr>
<td>STSW-IDP4PREMNT.zip</td>
<td>Binary</td>
</tr>
<tr>
<td>X-LINUX-PREDMNT</td>
<td>OpenSTLinux Expansion Pack in Source Code and with SD Card image</td>
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3 License agreement

The Edge to Cloud Solution enabling Condition Monitoring and Predictive Maintenance is subject to the ST Ultimate Liberty Software License Agreement (SLA0091) and third party license agreement. The Terms of Usage are mandatory to be signed the first time the user access the Dashboard at DSH-PREDMNT.
Revision history

Table 4. Document revision history

<table>
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<tr>
<th>Date</th>
<th>Version</th>
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<tr>
<td>25-Nov-2019</td>
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<td>Initial release.</td>
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<td>04-Feb-2020</td>
<td>2</td>
<td>Minor text edits.</td>
</tr>
<tr>
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<td>Changed name of Binary file from STSW-BFA001PREDMNT.zip to STSW-BFA1PREDMNT.zip</td>
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