IoT Sewer Blockage Detection

IoT Sewer Monitoring Device/Sensor Requirements

Commercial in Confidence

Contents

Revision History

Issue Number	Changes made by	Date Revised	Description of Change
01	A. Drenoyanis T. Wright	30 Aug 21	Initial issue based on requirements from extended trial
02	A. Drenoyanis	11 Oct 21	Summarised for external distribution

1. Background

Monitoring has traditionally been done using SCADA systems which provide very high levels of reliability and redundancy and have been used for many years on the water and sewer trunk systems. Even with the use of mobile networks and battery powered RTUs this technology has remained too expensive to extend down into the reticulation systems in great depth. Consequently, the customer has been relied on to report issues in the network such as low water pressure and sewer overflow or surcharge events once they have already created an impact for them.

The introduction of low power wide area networks coupled with battery powered IoT devices promises to provide a means of pushing monitoring down into the reticulation network with devices up to the customer premises.

Since 2017 Sydney Water has been undertaking IoT trials of which the deployment of monitoring devices in the sewer has been a key use case. The first stage of the trial demonstrated a device network operating on LPWAN technology could provide a means to monitor our networks more closely and respond to faults prior to customer impact.

As a first step this sensor network enabled an immediate response before or as soon as there is an issue which will impact a customer and the environment. The vision is for these device networks to utilize machine learning and analytics to provide predictive fault diagnosis capabilities so that targeted maintenance activities can entirely avoid an event which may impact a customer.

Now, in September 2021, with over 3,300 sewer blockage detection devices deployed in the field, this project has detected and prevented more than 190 blockages at environmentally high-risk sites in the, and now avoiding on average 15 overflows/month. Moving to productionise this project as part of Sydney Water's Environmental Improvement Program, and considering the lessons learned from the IoT Extended Trial, the device and sensor requirements have been refined to sustain mass deployment of devices commencing July 2022.

This document outlines the mandatory and desirable features for IoT sensor devices to fulfil the requirements of sewer monitoring.

2. Key Device Considerations

For this rollout Sydney Water would like to work with vendors to obtain products which meet the requirements set out in this document. The points below highlight some of the key drivers and considerations from the trials.

2.1 Environmental

Most of Sydney Water's assets are in the form of pipework underground which introduces several unique challenges for devices.

To keep the installation cost to a minimum, reduce any visual impact to the community and in some cases (where a manhole is in a road for example) there is no feasible alternative, it is not possible to install the device above ground (in a turret for example). The devices are typically installed in pits and in sewer manholes which poses an issue in both the environmental and communications aspects.

The sewer environment is typically humid, corrosive and there is the presence of vermin. Careful selection of the materials and sealing of any enclosure, cabling and instrument is critical to ensure that the device remains reliable and serviceable. Materials such as rubber (exposed will be attacked by vermin), aluminium and steel are known to be a problem. During the trial some devices had very high failure rates due to water ingress because of incorrect installation of seals and glands. In general, using an IP68 cable gland as the entry point for any cable to the enclosure with the battery and circuit board not potted is in practice not an ideal solution as pressure on the cable or incorrect adjustment at install leads to failure of the device. Devices which were potted or which used an IP68 connector system of plugs and sockets (which are potted around the wires) have proven to be more reliable in practice. While completely potting a device provides the best water ingress protection it also potentially prevents re-programming, access to any SIM and battery replacement. A robust IP68 enclosure and connectors without potting is perhaps the best compromise.

2.2 Installation and Life Cycle Cost

The total life cycle cost considerations are critical for the success of IoT devices. With relatively low equipment cost, the installation, ongoing maintenance and network operating costs contribute significantly to the overall cost of ownership.

It is important that devices are easy to install, reliable, have long battery life and stable firmware to reduce re-work and site visits. Total life cycle cost rather than initial cost will be the key driver for device selection.

In regard to installation, devices should have appropriate mounting brackets and/or attachment points to reduce installation time, improve accuracy/quality of the install and reliability of any attached instrument. Devices, sensors, and any associated mounting brackets should be designed such that entry into manholes is not required as this is highly undesirable from a safety perspective.

3. Device Features

The following sections outline the mandatory and desirable features for IoT sensor devices.

3.1 Network

It is mandatory that devices use an NB-IoT/CAT-M1 modem for network communication. The communication module used must be Telstra certified. Where the module supports both technologies, the user must be able to switch/use either mode.

It is desirable that a LoRaWAN variant of the device be available which could be deployed in areas of poor cellular network coverage. It is anticipated however that any LoRaWAN variant would only be deployed in very small numbers. For LoRaWAN devices it is mandatory that the devices support AS923. It is highly desirable that they can transmit at +19dBm or greater output power.

Devices with an option for IoT Satellite connectivity may also be considered for this subset.

3.2 Protocol

For NB-IoT/CAT-M1 devices it is mandatory that the device either uses an open/non-proprietary standard (e.g. MQTT/LWM2M/DNP3) or supports the Azure IoT Device Hub for communication of data to the server. Configuration and device management (such as firmware updates) of the device are preferably done with the same protocol (as commands directly to, or by loading of a file).

For LoRaWAN devices there is no mandatory message format. It is expected that any suitable LoRaWAN device is provided with both message frame structure specification, as well as a complete message payload decoder in javascript format.

3.3 Security

Devices should incorporate security by design principles. As a minimum this means that the basic principles of Integrity, Availability and Confidentiality are implemented in the design. Security features shall be configurable by the user (e.g. required/not required). Security shall not add a significant overhead in terms of data transfer, processing or memory.

3.4 Hardware

3.4.1 Case

It is mandatory that the device be IP68 – It is expected that the device will be submersed at times when installed in the field (due to current use cases being in sewer manholes and pits, protection from water ingress is essential). Cable glands shall not be used where they are the only means of protection for the internal circuitry or battery from the environment.

All exposed external materials should not degrade/corrode to reduce device performance for an expected lifetime of 10 years in a sewer environment or pit. Materials such as steel or aluminium are unsuitable.

The device must have mounting clips/bracket/holes etc so that it can be easily mounted.

3.4.2 Wiring Connector

It is mandatory that the wiring connection to external sensors utilise a potted IP68 connector (rather than a cable gland) to ensure that if water does ingress into the cable the water can damage the cable but not destroy the device. Cable glands in our experience have a higher failure rate than a potted connector. Any instrument or sensor attached via cable to the device must use a factory sealed/potted/moulded connector and not any kind of screw fit type connector.

3.4.3 Antenna

It is desirable that the device or variant has an external antenna connector (SMA type).

Where external antennas are provided with the device they need to be waterproof, and rated IP68 – The antenna needs to be enclosed completely/fully moulded.

3.4.4 Battery

For digital switch and monitoring applications with once/day send in expected life should be at least 5 years.

For analogue monitoring applications with once/day send in and 15 minute level readings the expected life should be at least 3 years.

Battery voltage and/or condition monitoring is mandatory

Use of a super capacitor/hybrid layer capacitor to extend/maximise battery life is desirable.

The expected battery life of the device will be considered as part of the device life cycle cost in evaluation.

3.4.5 Call in Trigger

A mechanism to trigger the device to immediately send in all data (e.g. reed switch triggered by magnet on case) is mandatory as it allows the device to tested quickly on install and/or setup.

3.4.6 External Supply

It is desirable that, in addition to batteries, the device or variant has the ability for an external DC supply. When provided it should automatically switch between internal and external supply (external when available). It is desirable that the external DC supply accept up to 30V to be connected to a DC supply including 12/24V sources. Where provided it is mandatory that the status of supply (internal or external) and the external supply voltage data should be available/exposed as data points to the server/IoT platform.

3.4.7 Pulse Inputs

Where pulse inputs are provided it is mandatory that they support a pulse frequency of 100Hz or greater.

3.4.8 Digital Inputs

Where digital inputs are provided it is mandatory that the inputs are compatible with volt-free (dry contact) e.g. Float switches or reed switches

It is desirable that the inputs are compatible with externally powered outputs up to 30V.

It is mandatory that the battery life of the device be provided based on a digital input being in the bridged state. This is as any switches are to be wired fail safe (normally closed).

Configurable hardware de-bounce is mandatory

3.4.9 Analogue Inputs

Where analogue inputs are provided, they must meet the following requirements:

At least 12-bit resolution is mandatory (16-bit is desirable)

A maximum of 1% error (of full scale) in reading across the input range is mandatory

A DC power supply pin for the analogue instrument is mandatory which is powered on when required (and with a user configurable instrument warm up/start up time).

3.4.10 RS232/RS485

Where a device supports RS232/RS485 serial communications it should support Modbus communication with user configurable baud settings and timeouts.

A DC power supply pin for the serial device is desirable which is powered on when the serial communication is required (and with a user configurable instrument warm up/start up time). Supply voltages of 5-12V DC with a capability of 50mA+ is desirable.

3.4.11 Submersion

It is desirable that the device has a submersion sensor (e.g. capacitive switch) to detect and alarm when the device is submersed in liquid.

3.4.12 Identification

It is mandatory that a unique serial number of the device (e.g. IMEI/ICCID for NB-IoT/CAT-M1, EUI for LoRaWAN) in the form of characters and barcode shall be visible without opening of the enclosure (e.g. sticker, etched in case etc) so that the device can be uniquely identified. All labelling on the device must be made suitable to ensure they remain readable and attached to the device for the life of the install.

3.4.13 Protection

It is mandatory that all external I/O and inputs have electrostatic discharge (ESD)/transient voltage suppression (TVS) protection.

It is desirable that all inputs are fault tolerant to +/-30V.

3.5 Firmware/Bootloader

3.5.1 Update Features

For NB-IoT devices it is mandatory that the device firmware can be updated over the air (this may utilize CAT-M1) and locally.

For NB-IoT devices it is desirable that the device bootloader and modem firmware also be updatable over the air and mandatory that it can be updated locally.

For LoRaWAN devices it is mandatory that the device firmware can be updated locally

3.5.2 Configuration

For NB-IoT/CAT-M1 devices it is mandatory that the device can be locally and remotely configured for all user defined settings. When the device sends in data and loads a new configuration all data should first be uploaded before the new configuration is applied so that no data is lost. On change of configuration the device should restart/reboot (if required), apply new settings and send in (to confirm that the new configuration has been validly applied). It is mandatory that the device configuration can also be remotely uploaded.

For LoRaWAN devices it is mandatory that a downlink command set be available to change key device parameter settings such as frequency of transmit, alarm deadband time etc as the use case necessitates.

3.5.3 Communication Features

For NB-IoT/CAT-M1 devices it is mandatory that the firmware support the following communication features which can be configured by the user:

- APN setting

- Server IP address/URL and port
- Frequency of data upload to server and time of day offset
- Frequency of data upload to server if alarm condition active

For LoRaWAN devices it is mandatory that the firmware support the following communication features which can be configured by the user:

- Adaptive Data Rate (ADR)
- Over the Air (OTA) methods of registration/activation.
- Frequency of data transmit when no alarm condition active
- Frequency of data transmit when alarm condition active

3.5.4 System Monitoring

For NB-IoT devices:

It is mandatory that the following data points are available:

- Network Signal Strength/RSRP, SNR, RSRQ
- Battery Voltage/Condition Indicator
- Device firmware, bootloader and modem firmware versions
- Error code(s) for system faults/configuration error, events, device restart etc

It is desirable that the following data points are available:

- Temperature

For LoRaWAN devices it is mandatory that the following data can be transmitted in a message:

- Battery Voltage/Condition Indicator
- Device firmware version

It is desirable that the following data points are available:

- Temperature
- Network Signal Strength/RSSI

3.5.5 Diagnostics

For NB-IoT devices it is mandatory that local diagnostics be available and desirable that diagnostic information (e.g. log files) can be remotely obtained. Diagnostics at a minimum must include modem commands with any status responses/errors, changes in the state of or sampling of used/configured I/O and communication with the server. Where serial communications are provided diagnostics for these must include transmitted/received bytes. All diagnostics must be time stamped.

For LoRaWAN devices it is mandatory that local diagnostics be available.

3.5.6 Reporting of Data

For digitals, pulse and any internal analogue data points it is mandatory that the current value is reported along with all buffered historical data at the time of transmission.

For analogue (instrument) points which are sampled at discrete times all buffered historical data should be reported at the time of transmission.

3.5.7 Data Usage

Data usage is a significant life cycle cost consideration due to its impact on battery life and network costs. The target data usage for NB-IoT/CAT-M1 devices is < 1MB per year for reporting of data daily using float switch instruments and < 2MB per year for analogue instruments at 15-minute sampling. Data usage will be considered in the device life cycle cost analysis.

3.5.8 Bootstrapping

The device must be capable of a bootstrapping process that requires only it's registration on the server and waking of the device to fully configure and deploy it.

4. Sensor/Instrument Requirements

For this mass deployment it is anticipated that the sensors deployed will be a mix of analogue level and float switch type instruments. The trials have shown that float switches provide an effective reactive alarm to detect chokes in the sewer network, but the vision is to be able to proactively detect partial chokes before they develop further. To this end analogue levels will provide the data for deeper analysis for earlier detection and although it is preferential for all installs to be analogue levels it may not be cost effective at this time to do so.

The requirements for these instruments are as follows:

- Rated for permanent submersion
- Construction/materials suitable for installation in manholes – case/body capable of withstanding turbulent flows and any impact to manhole etc, resistance to corrosion, gases, vermin present in sewer
- Analogue level instruments must use non-contact measurement principles (hydrostatic instruments for example are not acceptable) and must be capable of measuring the sewer depth in the channel where the manhole depth is less than 3m to an accuracy of 5mm or better
- Must be capable or have a variant with 6m measurement range for analogue level and up to 10m cable option for float switches

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