Digital twins for water networks

An Altior application white paper

Smart metering with SWaRM

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Introduction

This document describes SWaRM, a smart water metering application developed on Altior, Inkwell Data Ltd.'s digital twin platform.

The purpose of this paper is to familiarize the reader with the concepts of digital twins and the role they can play in the provision of industrial Internet of Things ("IoT ") services for water companies.

Although technical in nature, this document is intended for metering and IT executives in water companies facing the challenge of defining and deploying a digitalization strategy and building a smart infrastructure around their existing water network resources.

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The digital twin for the water utility

As the term itself implies, a digital twin can be broadly defined as a digital replica of a physical asset.
From physical simulation to industrial processes models, digital twins are a way to prototype and evaluate the effectiveness of a digitalization strategy.

Altior is a digital twin enabling technology created by Inkwell Data; it is designed with a focus on the domain of industrial IoT applications and services.

Altior components allow the user to define digital twins for most sensors and devices used in industrial applications, as well as to create virtual networks to communicate with the physical world.

In the smart water application domain, Altior digital twins are built for devices such as meters, pressure sensors and data loggers, as well as their communications infrastructure, including public cellular networks and private low power, wide area networks (LPWANs).

For more information on the digital twin features of Altior, please refer to [1].

Water metering: AMR and AMI

The digitalization of water metering is a complex process as it involves both regulatory, technical as well as commercial considerations.

Standard water meters must comply with strict technical standards for accuracy and precision, and are subject to specific installation and positioning constraints, as well as many other legally relevant demands.

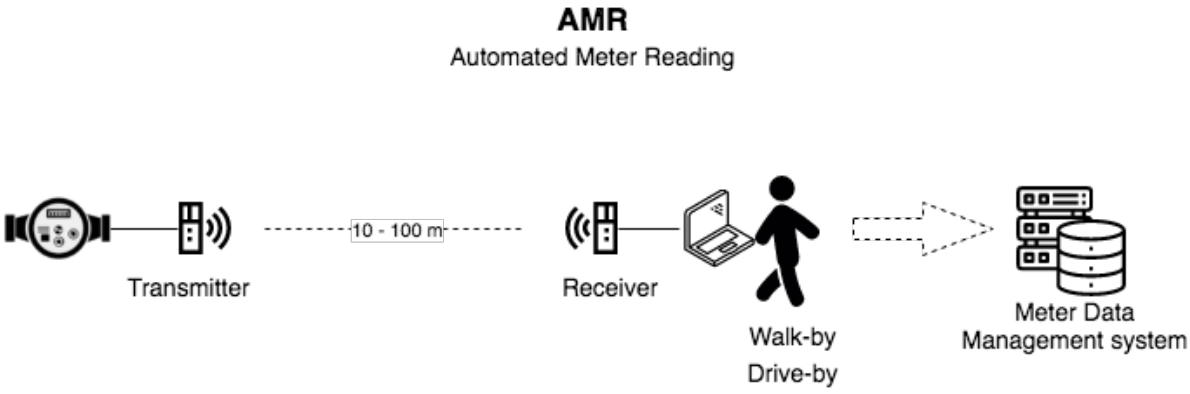
To simplify the meter reading task, a water meter can be upgraded to a communicating water meter.

The upgrade usually involves the addition of a data communications component (usually a radio frequency transmitter) that collects the consumption data with a sensor attached to the meter and transmits the reading to a collection system, and ultimately to a data management system where the consumption data is used for validation and billing purposes.

Popular water meters support some form of automated meter reading (AMR), generally employing a battery powered radio transmitter add-on operating on license-free ISM frequency bands. Depending on the geographical area, the most commonly used frequencies for AMR are 868 MHz for Europe and 900-928 MHz for North and South America.

Once the AMR transmitter is installed and properly commissioned, meters reading operations require a receiving unit that is employed by an operator in walk-by or drive-by mode.

The AMR transmitters continuously broadcast the consumption data that are picked up by the receiver at specific times; the limited power of the AMR transmitters requires some proximity to the receiver (10m to 100m) with the interference mostly harmless.



Although AMR offers the advantage of not requiring a physical access to the meter by a field operator, it is not considered as true smart metering, with the meter only providing a periodic water consumption reading with no additional data.

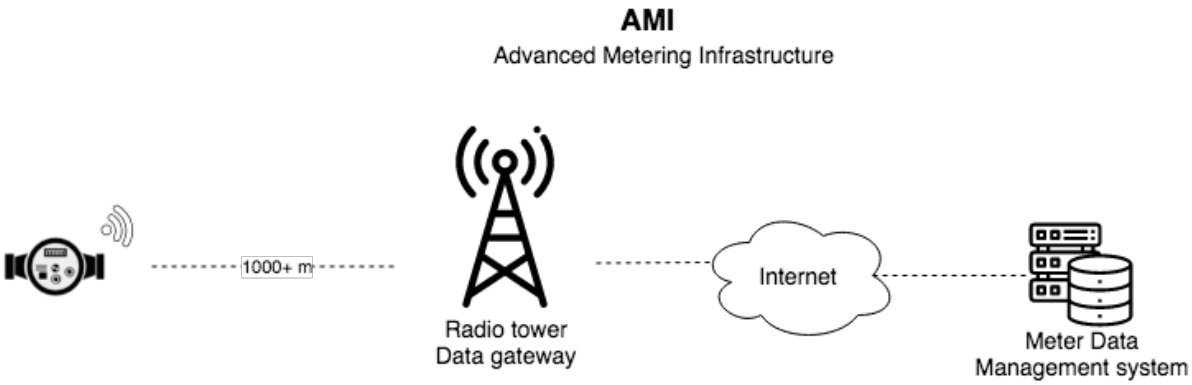
Smart water meters are an evolution on traditional AMR meters, typically integrating sophisticated electronics to collect not just a single meter reading, but able to sample and store multiple data points over a variable period of time; this allows the creation of consumption profiles and the implementation of basic added value functions such as leak detection.

In addition, smart meters benefit from enhanced anomaly and fraud detection capabilities and may even support an integrated shut-off valve, as well as basic sensing capabilities such as temperature measure.

The communication modules included in the water smart meters support what is known as an "infrastructure mode", hence the AMI moniker for Advanced Metering Infrastructure.

Smart meters for AMI employ different transmitters' technologies to access the network infrastructure.

The network technologies supported may be public and operating on licensed spectrum, such as 2G GPRS, 4G LET and NB-IoT and LET Cat-M, or LPWAN networks operating on unlicensed spectrum.



AMI solutions are preferred to AMR for large roll-outs, as they typically prove more cost competitive than walk-by / drive-by meter reading, and the supporting infrastructure can be used for additional water network services.

Water metering challenges

However, implementing a truly effective water smart grid requires careful advance planning.

Most water companies have already implemented some form of ARM; a few more are in the process of implementing AMI networks, but neither AMR nor AMI are, by themselves, enough to constitute a true smart water network.

A truly successful smart metering project needs to address a wide range of interested participants and stakeholders, with differing, and at times, conflicting objectives.

The accounting department needs accurate and timely water consumption data for billing; the metering department needs accurate and reliable meters to comply with local regulations; the IT department needs to safely collect and store the metering data, including notifications of events and alarms; procurement requires cost-competitive solutions; operations needs easy to install and operate devices, whilst network engineering needs full control of the communication network performances.

The success or failure of a smart metering project therefore depends on addressing all these demands within a reasonable financial budget and timescale.

A conventional, vendor-driven, smart metering project is however predominantly based on the technical features of the proposed meters and communication infrastructure as well as the marketing capabilities of the specific technology vendors.

In this set up, there is an inherent risk of a cognitive bias; by choosing a specific smart metering technology, the end-user will partially solve its problems, but not entirely, on the basis that "some solution is better than no solution".

This unfortunately results with smart metering solutions in which the characteristics of the chosen technical solution of the vendor take priority over the actual business requirements of the end-user.

Metering infrastructure technology is typically sold as a proprietary solution, with inevitable serious vendor lock-in risks for services expected to last for the entire lifecycle of the meters, commonly 10+ years. In the world of technology, this represents an eternity.

Designing a water smart metering infrastructure should not be limited to addressing an intermediate problem, but instead should focus on long term considerations that are not just technical in nature. A number of these issues are reviewed in [2].

Rethinking water smart metering

Implementing smart metering is far from a trivial task for water companies and municipalities given the large number of unknowns and the requirement for multi-disciplinary, cross-domain capabilities, with proven know-how and expertise. It starts with handling detailed, often complex, regulatory requirements.

Can the inherent risks associated with a large-scale water smart metering project be addressed upfront?

Inkwell Data's answer is a clear yes, through the implementation of a digital twin system architecture.

The Altior digital twin platform enables the prototyping of smart metering services, providing the user with the freedom to test one or more smart metering technologies, without wasting time and resources, and creating a knowledge-base to underpin the success of a large roll-out.

At Inkwell Data, we call this the **Holistic Metering Infrastructure** (HMI): an infrastructure including not only meters and networks, but also applications and processes to implement a coherent vision of the smart water metering services.

- HMI is by nature holistic, as it integrates all the requirements of the many relevant stakeholders in the metering process, including the most important: the end user.

- HMI is, in addition, technology agnostic and can be applied to existing as well as future metering and communication network technologies. A "future-proof" approach to smart water metering services.

The cornerstone of this HMI is Inkwell Data's **SWaRM,** a smart metering service built on top of the industrial IoT digital twins and the middleware features of our Altior platform [2].

SWaRM allows for the implementation of a unified meter reading and management, regardless of the underlying transmission technology, as long as they have a digital twin.

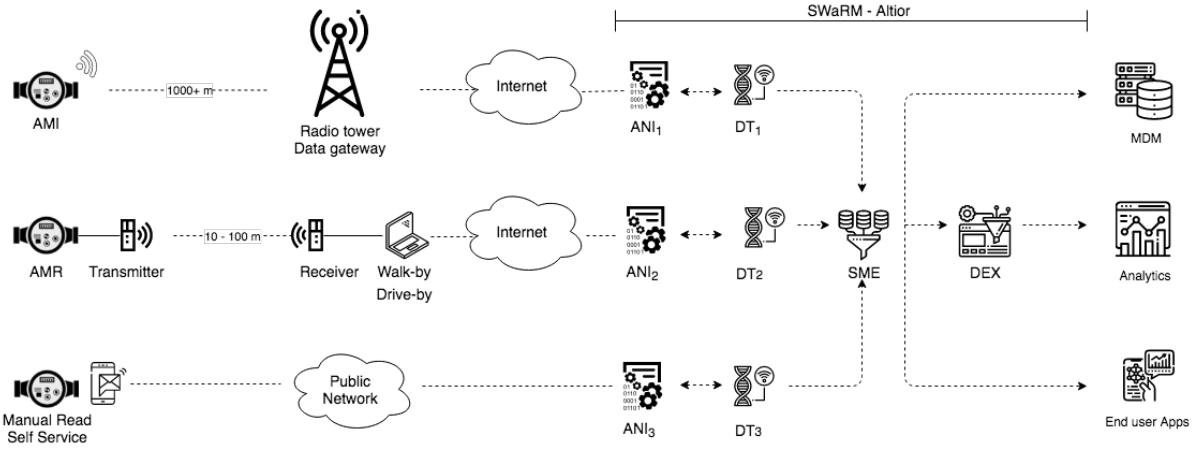
Out of the box, SWaRM supports:

- Smart meters equipped with radio frequency communication interface and operating on license free wireless network infrastructure (including, but not limited to wireless M-BUS, Wize, LoRa WAN, RPMA, Weightless);
- smart meters operating on cellular network infrastructure and cellular LPWAN (2G, 4G, NB-IoT, LTE Cat-M);
- legacy meters equipped with radio frequency communication transmitters for Automated Meter Reading and operating on unlicensed frequencies (868 MHz, 169 MHz); and
- legacy meters with optical reading and data transmission by means of self-service[1] or by smartphone application.

This is possible because using the digital device twin, SWaRM performs on the raw metering data what is known in the telecommunication industry as data mediation[2].

Holistic metering infrastructure based on Altior and SWaRM has a multi-layered architecture:

The Holistic Metering Infrastructure



At the data transport level, Altior creates a virtual network interface (ANI, Altior Network Interface), where the binary frames coming from the smart meters are stripped of their low-level transport protocol.

For example, in the case of DLMS/COSEM smart meters using the wireless MBUS transport protocol, the COSEM application protocol data units (APDUs) are separated from the wireless MBUS "envelope", and then sent to the digital twin (DT) for further processing.

At the digital twin level, the usually encrypted binary data is further processed by a security service provider, enabled by Inkwell Data's security platform, Aegis [3], and rendered in unencrypted form.

For example, by using a utility provided application, a text message or IVR call centre.
[2] Data mediation: semantic transformation of **data** structure and **data** content to establish semantic equivalence of different representations

A key feature of Altior digital twin and middleware is that all data connections, both physical and logical, use an end-to-end encryption mechanism for endpoint authentication and single operation authorisation. This added security layer integrates or complements the physical device native data security method.

The un-encrypted raw application protocol data in the APDU is mapped to a high-level data structure with an appropriate protocol decoder (such as COSEM or OMS), also provided by the device twin.

The high-level data structure is then stored in the digital twin state data and processed by the SWaRM mediation engine (SME) for persistent storage and other usage of metering data.

The Altior digital twins are optimized for fast encryption/decryption, and coding/decoding of binary data. In terms of raw processing capabilities, on a commodity server hardware (single quad core CPU), SWaRM can process an encrypted binary 128 bytes data frame from an OMS compliant water meter in ~80µs, that is, roughly, 1,000 OMS data frames per second.

Although this figure does not include the wireless network latency and refers to data frames delivered by the Altior network interface, one can see readily why scalability is not an issue for Altior-powered applications.

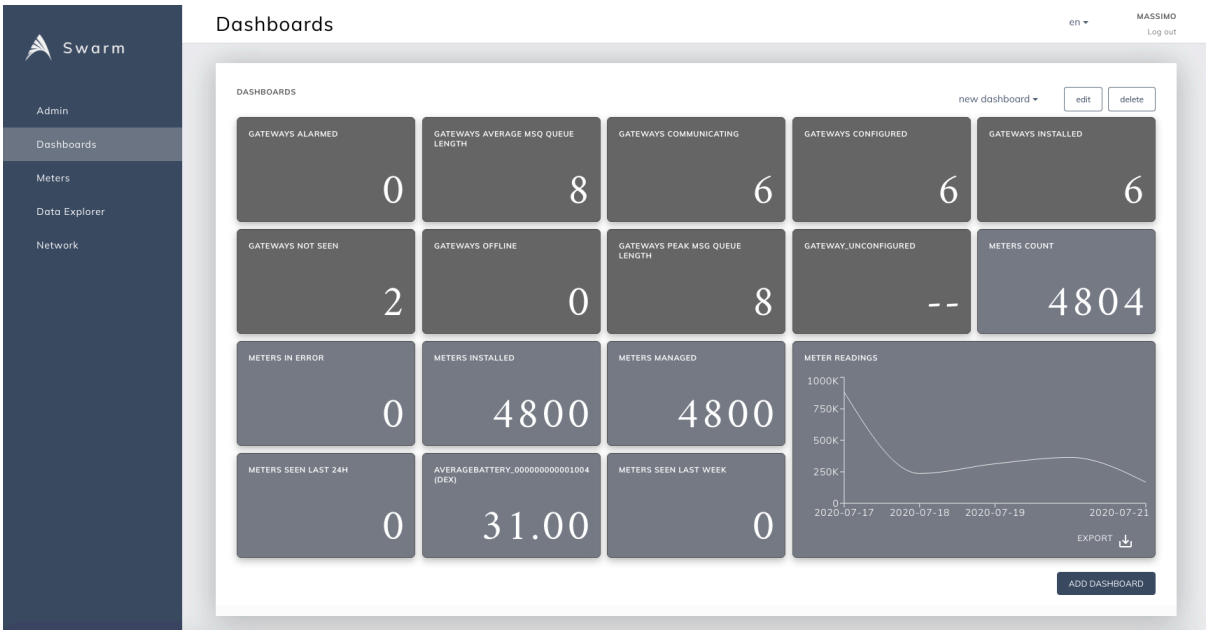
The digital twin stated data values and properties for every water meter managed by SWaRM are also made available to other Altior applications, as well as third party applications through the Altior API or the Altior data connectors.

SWaRM and the holistic metering infrastructure

SWaRM is designed for an easy integration with the existing IT infrastructure of water companies. The web-based SWaRM user interface is highly customizable without programming. The SWaRM user interface can be accessed by any modern browser supporting the TLS security standard. The function menu gives access to the main SWaRM functions.

The SWaRM dashboard

The main page of SWaRM is a dashboard that gives an at-a-glance view of the smart metering infrastructure status.



The dashboard can be easily configured to show the most important metrics in real time and can be used as a wall screen in the network operation centre. Every metric is contained in a “tile” called a widget.

The type, nature and representation (numeric, graph, etc.) of a metric in the widget are user defined, and the placement of the widget in the dashboard page is also customisable with a simple drag and drop system.

SWaRM supports multiple custom dashboards and the system administrator can assign specific dashboards to users and users’ groups.

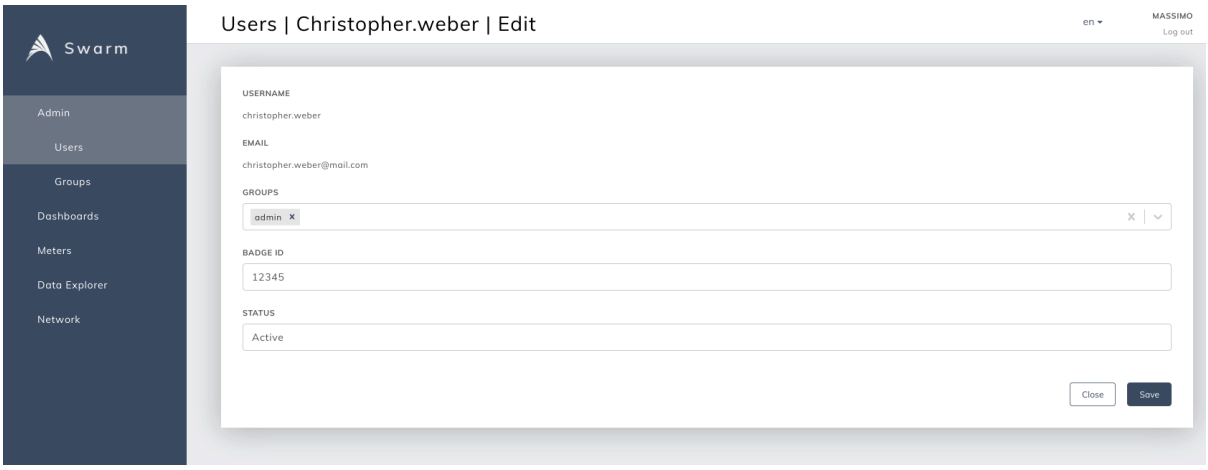
For example, the system administrator may define a dashboard representing the overall performance of the smart metering system, including both metering information and network statistics.

The metering supervisors can be provided with a dashboard showing the detailed metering metrics, whilst the network supervisor or IT department can use a custom dashboard with detailed communication network statistics and meter data management statistics.

Users management and authentication

Users and groups administration in SWaRM allows fine grained privilege assignments and access control to SWaRM functions.

The user accounts can be managed directly from the intuitively-designed administration page, and for large organisations with many potential users, SWaRM supports a single sign-on feature.



The SWaRM user account manager can interoperate with other user accounts and directory systems supporting the standard OAuth 2.0 and Active Directory authentication.

Every operation performed by any user in SWaRM is timestamped and logged for security reasons.

Meter management

In effect, SWaRM provides an intuitive meter management system, designed to handle millions of devices.

Through the meter administration page, the user has an overview of the most vital installation statistics, with the option to go into granular detail through a couple of clicks.

The smart meters and transmitters supported by SWaRM include all the water meter device twins available on Altior; this feature gives the HMI flexibility to include new meter types on existing metering infrastructure, without any change of procedures.

The SWaRM mediation engine supports most of the common meter application protocols such as EN 13757, OMS and DLMS/COSEM and their associated security modes.

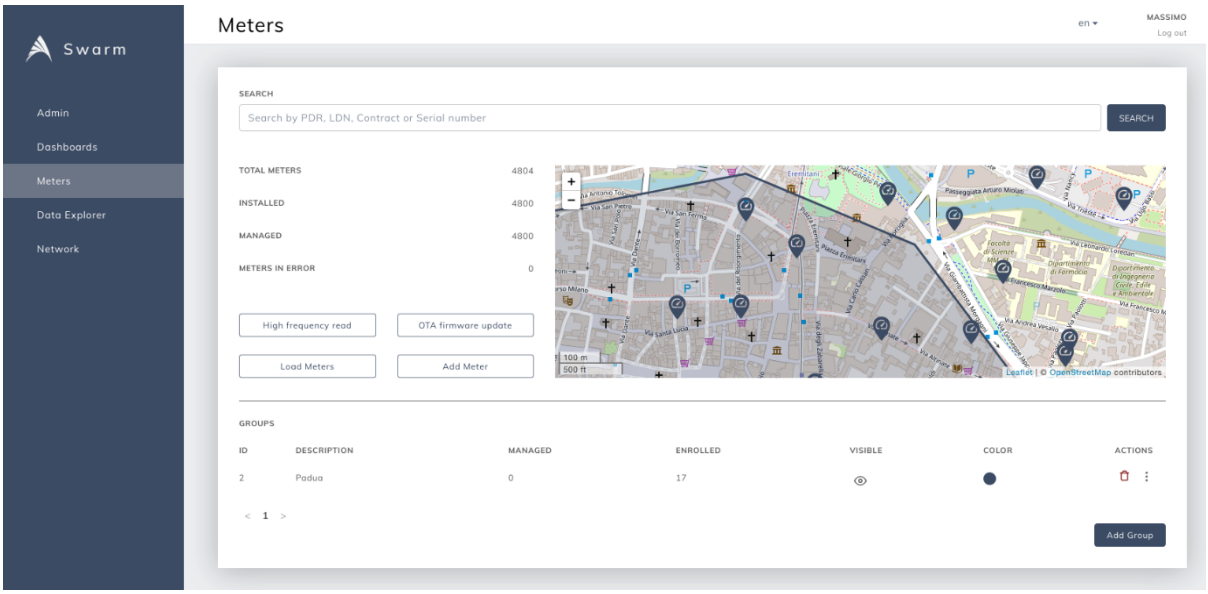
For a proprietary metering protocol support, an Altior digital twin is developed and included.

When adding a meter device to SWaRM, it is possible to select the meter type from an Altior library of supported smart meters or data transmitters[3].

Adding a meter from the SWaRM user interface automatically creates the corresponding digital device twin instance on Altior.

The meter's installation data can be added manually by an operator; on most real-life situations, SWaRM will import the meter's definitions (including security data like encryption keys) from the meters' vendor provided files, allowing a safe bulk meters data base update.

[3] Non communicating (legacy) meters can also be managed by SWaRM using a special network interface on Altior. This limits the data available from those meters (like alarms) but still allows for a unified billing data exchange.



In addition to their standard properties and attributes, meters can be given specific custom tags (such as class or category, or SIM card cellular operator ID) to ease search and filtering, and they can be also included into one or more geographic district or meter groups.

In the meter details page, all the configuration data is displayed including:

- installation address and GPS coordinates;
- installation and commissioning date;
- meter firmware version;
- meter/transmitter type and manufacturer and brand;
- for cellular based meters: SIM card and IMEI data;
- radio communications configuration data;
- data encryption configuration;
- battery status;
- metrology and system alarms;
- district (group) and custom tags; and
- valve status (if a valve is present).

From the meter details page, it is also possible to schedule and send a command message to the meter (like a clock synchronization).

Also available is the list of all the data notifications received by the meter including metering data (volume), metrology status, system status and RSSI for LPWANs smart meters and transmitters.

The volume data is shown in a graphical view with a daily, weekly, monthly and yearly window.

All the meter's data can be exported in CSV (comma separated value) or in XLS spreadsheet format.

Most meter management operations on SWaRM can be performed on the whole meter database, or can be applied to specific districts.

A metering district or group can be defined by simply drawing the district perimeter on a map and assigning a district name, or can be defined when bulk-loading the meter definitions into SWaRM.

For example, an over-the-air (OTA) firmware upgrade can be scheduled for a specific group of meters identified by a common tag or a high frequency meter reading can be scheduled for a meter district to support a water leak detection procedure.

The tagging and grouping feature of SWaRM meters means it is very easy to extract metering data from single or multiple groups for the purpose of data analysis (see Dex paragraph below).

All the metering data, including event and alarm notifications, are collected and processed by the SWaRM mediation engine and stored on an external database. SWaRM supports all the popular relational database (SQL) as well as No-SQL databases.

For simple billing purposes, SWaRM can filter and send billing data to legacy billing platforms using periodic scheduled (S)FTP file transfer.

Using the Altior platform connectors, the metering data can be exchanged with third party applications such as ERP and CRM systems using common web standard APIs or by popular message brokers supporting the MQTT and the AMQP standard.

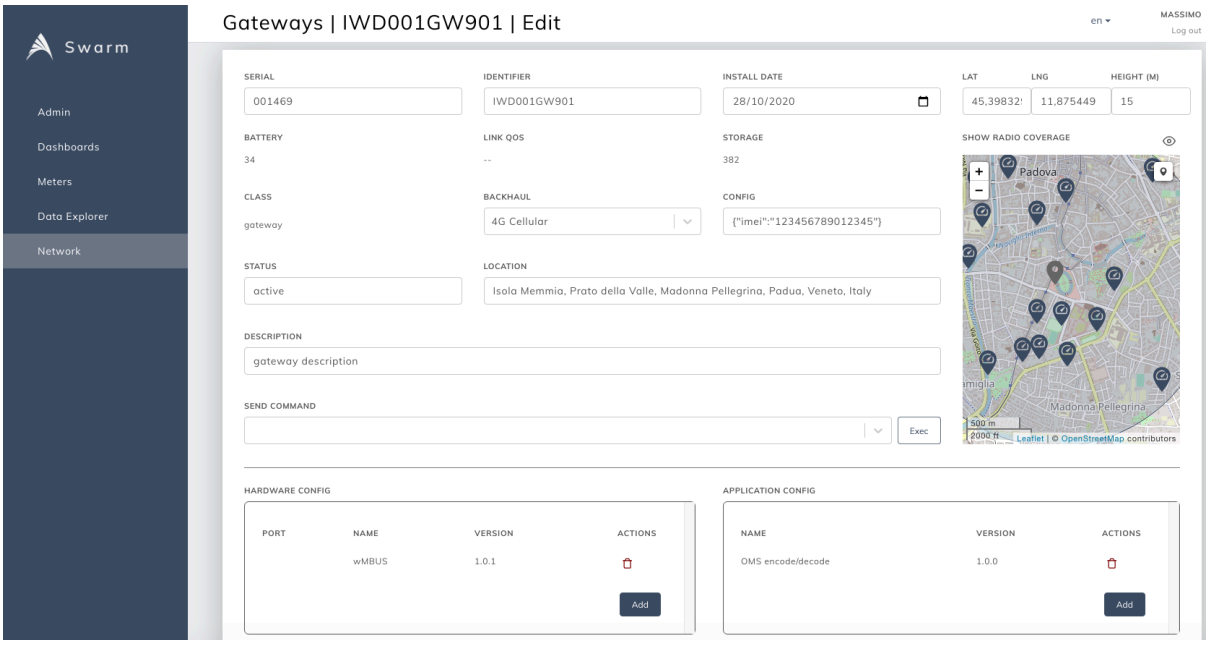
Network management

For water utilities implementing their own private LPWAN infrastructure, SWaRM provides the tools to manage the network devices and operate the network with a simple user interface.

Although SWaRM has an extended support for Inkwell Data's Altior Edge Gateway (AEG), any data gateway or data concentrator can be supported by an Altior digital twin.

SWaRM supports most popular and open standard based LPWAN devices and protocols operating on the unlicensed spectrum such as wireless MBUS, Wize from Wize Alliance, LoRa and LoRaWAN, RPMA and Weightless.

Thanks to the digital twins, SWaRM manages all the different LPWAN devices with the same high-level interface, and in case new network technologies need to be supported, it is a simple matter to add their digital twins without changing the network management procedures.



From the data gateway management page, it is possible to get an overview of the network health status or access the detailed page of a single data gateway.

The information provided for every gateway includes:

- installation address and GPS coordinates with antennae height:
- installation and commissioning date;
- gateway firmware version for all the wireless interfaces;
- meter/transmitter type, manufacturer and brand;
- radio communications configuration data for all the wireless interfaces;
- data backhauling configuration (wireline, fibre and cellular wireless are supported);
- the theoretical radio coverage (represented as a circle) and meters included; and
- for edge devices: the list and configuration of the edge computing applications.

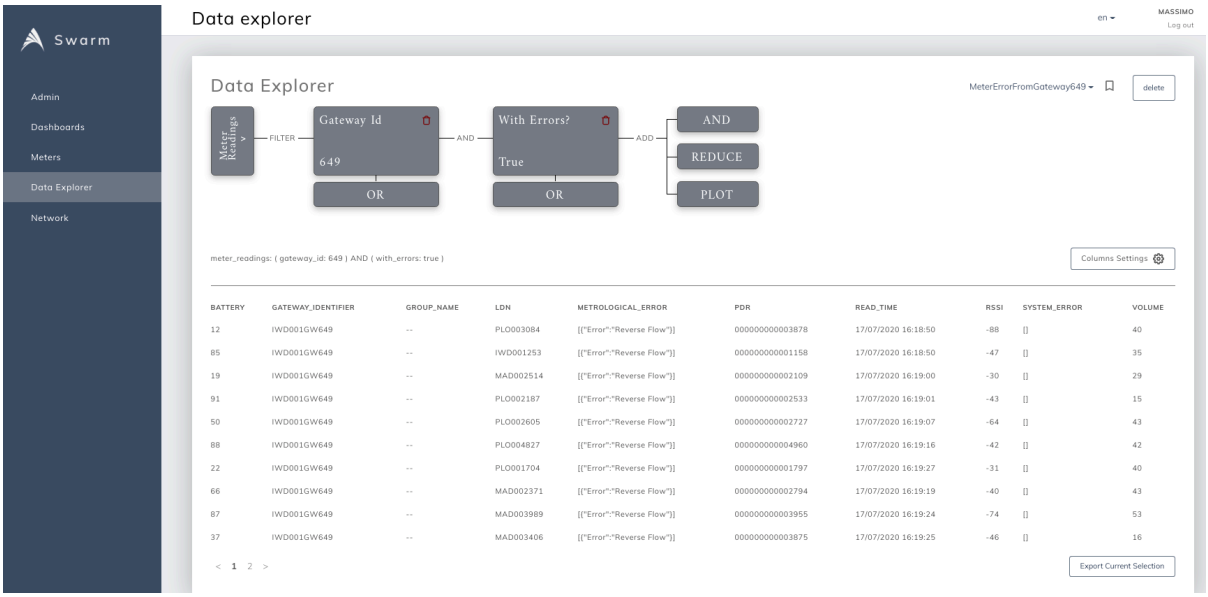
From the details page, it is also possible to send management commands to the data gateway like a clock synchronisation, a firmware version update or a reboot/reset command.

For edge computing devices like Inkwell Data's own AEG, SWaRM can install on the data gateway special functions, such as binary frames encoders/decoders. real time inbound data frames deduplication or multiple protocols handlers.

The SWaRM data gateways management features include the list of all the events, warnings and alarms that can be downloaded in CSV or XLS format.

Dex

The Altior Data Explorer (Dex) is an Altior function integrated in SWaRM, to provide the user with a tool to build their own data widgets to be included in the various SWaRM dashboards, as well as acting as a tool to explore and extract meaningful data from the SWaRM persistent metering data storage.



Dex allows the creation of complex database queries using logic (and, or) and relational operators (like greater than, less than, etc.) with a “wizard” like interface.

It is possible to define any kind of filtering on the selected database combining meter data and network data, and to then assign a name to the result for reuse.

In the example in the above figure, a query like “find all the meter readings received by gateway 649 where the condition of the meter was in error” was built with a few clicks and then assigned a meaningful name “MeterErrorFromGateway649”.

Dex also includes powerful operator like “reduce”, which can take a whole list of data and apply a mathematical operation (e.g. the average) to output a single numerical value which can be used in a dashboard widget.

All the results from a Dex query can be further customised selecting what columns (data field) to display and in what order.

This feature is particularly useful when the Dex query result is exported in the CSV or XLS format for further processing with, for example, analytic tools.

Conclusions

SWaRM offer a holistic metering infrastructure that allow water utilities to implement a smart metering strategy in an agile manner.

A SWaRM roll-out can be multi-staged and result-driven, with every stage of the implementation providing feedback for the next stage. Furthermore, a SWaRM stage can involve a limited number of meters in different environments (urban, suburban and rural) to evaluate the best technology combination.

We believe that the freedom to test with different metering and networking technologies and the capability to include legacy metering systems are the best way to minimize the risks in a massive roll-out campaign and avoid the risk of vendor lock-ins.

The continuous development of new metering device twins by Inkwell Data Ltd. and its Altior ecosystem partners means continuous innovation with backward compatibility and support.

Although SWaRM allows the rapid prototyping of smart metering services with a limited number of water meters per stage, the Altior architecture makes it very easy to escalate the prototype to a massive roll-out by simply adding more hardware resources.

Designed for mission-critical applications, the Altior industrial IoT platform can scale up incrementally as the number of meters handled and the business requirements grow, limiting the quantity of computing resources required to set up a SWaRM service.

Available on public or private cloud, on a hybrid cloud or on premises, SWaRM is independent of expensive cloud framework and foundries and the easy transition from a deployment environment to another allows for an easier IT resources budgeting.

SWaRM and the holistic metering infrastructure are a way to future-proof the technology investments made by a water company, and a powerful tool for the realization of the smart water grid.

References

[1] Digital twin for industrial IoT with Altior - Part 1: digital twin design. Available at https://inkwelldata.com
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[3] Digital twin for industrial IoT with Altior - Part 3: digital twin security. Available at https://inkwelldata.com

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