Outcomes, Insights, and Best Practices from IIC Testbeds: Intelligent Urban Water Supply Testbed

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This article gathers information from the Industrial Internet Consortium's (IIC) Intelligent Urban Water Supply Testbed. The information and insights described in the following article were captured in an interview conducted by Joseph Fontaine, Vice President, Testbed Programs at IIC with Dr. Shi-Wan Lin, CEO and Founder of Thingswise, LLC. Shi-Wan is an IoT Technologist who serves as Co-Chair of the IIC Technology Working Group and the Architecture Task Group.

TESTBED PROFILE

The Intelligent Urban Water Supply Testbed is about building an intelligent water supply management system. Obviously, water has been an important element in our lives and it has become an increasingly scarce resource due to the growth of populations and the over-usage of natural resources. The challenges in water supply are aggravated by the lack of visibility into water supply operations including the equipment's operational state, if they are running normally and how well they are running.

Water quality is undoubtedly of great importance. However, visibility into the water quality is often lacking in various locations of the water supply pipeline network. Energy is another issue. With the rapid growth in the urban settings in China in the past 30 to 40 years, a great number of high-rise buildings have been built. To supply water to these buildings, large water pressurized pumps are installed in these buildings. These water pumps consume substantial energy. Because of lack of visibility, it is often not known whether their energy use is efficient.

WPG is a leading water supply manufacturer in China and among the very first members of the IIC. They recognized early that the industrial internet offers great potential for improving water supply management. WPG has been thinking of ways to adopt industrial internet technologies in the water supply sector, making them scalable and at low cost, so that it can benefit water supply management for a large number of cities. In doing so, they look to transform their business model from a conventional equipment manufacturer to an intelligent water supply service provider as well.

As a main category of water supply equipment, water pumps are sophisticated industrial automation systems controlled by Programmable Logic Controllers (PLCs). However, once installed, they often operate independently without connectivity to some centralized management system. If a pump fails, someone on the property would make a call to the water supply company, or to the manufacturer before technicians can be dispatched to repair it. This reactive process tends to have a long turnaround time leading to a longer period of service outage. Furthermore, repairs after failures are often more costly. With the industrial internet, connecting the equipment or sensors to remotely collect data from them, and applying analysis to the data to monitor and detect early signs of failure, may greatly improve this process and offer other improvement, e.g. in energy efficiency and water quality monitoring as well.

The purpose of the Intelligent Urban Water Supply Testbed is to determine the best ways to connect to the equipment and at the same time build a cloud-based service to collect and analyze large amounts of data from a great number of equipment.

The first technical objective is to provide visibility remotely into the operation of the equipment and simultaneously enable a faster response to detected problems.

Secondly, by applying data analytics, equipment anomalies can be detected and failures diagnosed automatically. Thus, the reliance on human operators for these tasks will be reduced. When the number of equipment increases to tens of thousands, it is difficult or practical to employ enough staff to manually monitor the operation of the equipment.

Traditional Supervisory Control and Data Acquisition (SCADA) systems usually rely heavily on manual work in operations. It is expected that more and more advanced analytics can be applied to perform these types of tasks and gradually reduce the reliance on humans. From the technical perspective, the first objective is to analyze the data collected in the large amount of equipment, gain insights into their operations and progress from simply monitoring to diagnosing to predicting failures.

The second technical objective is to monitor energy usages and increase efficiencies. It is a common practice that once these pumps have been installed, they keep running with their initial configurations. However, some of these configurations may not be optimal, e.g. because of the incorrect initial assumption of the usage patterns, and consequently energy efficiency is not optimal. When many pumps are connected, energy usage profiles can be established in the context of the actual water usage patterns. The outliers can be identified much more effectively and can then be addressed.

The third objective relates to water quality. In order to ensure water quality, the first step is to enable visibility. Visibility is achieved by deploying water quality measurement instruments, across the water pipeline network. Yet, these instruments are too expensive to install in large numbers to monitor the whole network's water quality. On the other hand, if small numbers of instruments are installed in strategic locations, data collected from these instruments can be analyzed to infer water quality across the pipeline network based on its topology.

The last objective of the testbed is to seek to balance the water supply demand versus water supply quality. In some buildings, water tanks store water temporarily to respond to peak usage hours. However, water quality degrades over storage time. By analyzing the water use pattern, the water storage level can be optimized in response to the water use patterns, satisfying the water demands and at the same time maintaining the water quality.

Goals

Suppose each water supply company establishes a system and operates it by themselves. In a country as big as China, hundreds of similar systems would be built and clearly this is highly inefficient. WPG's goal is, instead of each water supply company building such a system – one by one, on their own, re-inventing the wheel, one after another – to establish these technological capabilities in the cloud and offer these capabilities to the water supply companies as a service.

In this way, WPG can lower costs because they are providing these technical capabilities in the cloud at scale, making it more affordable for the water supply companies to leverage and benefit from the latest technologies. With this, WPG seeks to transform themselves from a traditional manufacturer to a service provider by working very closely with the water supply companies to deliver value to them as partners.

PLANNING

Initially, from the technology perspective, the testbed established its service-in-a-cloud platform, so this service can be accessible across the country. Then they deployed their software and provided data processing, analytics and business applications in the platform. During the initial experimentation, a number of gateways were installed connecting to water pumps in customer premises and data was collected from these gateways to validate the system.

WPG has continued to engage the potential customers – the water supply companies – and it turns out that many of them are very interested in these services. So at this time of this interview, there are currently about 2,500 water pumps connected to the testbed in approximately 100 municipalities in China.

There are two approaches to connect to these pumps: one is directly connecting to these pumps by deploying IoT gateways. Secondly, some of the water supply management companies have built their SCADA systems prior to this testbed. In this case, the testbed bridges the SCADA systems into the testbed systems.

Much of the hard work remains in collecting enough quality data and building analytics models so that models can be applied back to the runtime environment to capture meaningful patterns in near real-time to achieve the technical goals outlined above.

IIC ECOSYSTEM

The Intelligent Urban Water Supply Testbed participants came together in the ecosystem fostered by the IIC. WPG came to Boston in 2014, wanting to learn about and get involved in the industrial internet. Engaging with the newly formed IIC, they found these ideas very important in solving challenges faced by companies in the water supply sector. It is within the IIC ecosystem that the current members of the testbed participating companies met, engaged and planned out the testbed.

WPG has a large business stake in making this successful. They bring the domain knowledge, business use cases and customer relationships. They know details about their equipment, the behavior of the equipment and how the behavior is reflected in the data that are collected.

Thingswise offers a streaming analytics platform that adapts and innovates the latest Big Data, Machine Learning and Cloud Computing technologies into a turn-key solution for IIoT. It is among the very first systems in the industry by design, capable of performing on-the-fly analysis of live data streams at low latency distributed in the Cloud, on the Edge or in IoT gateways. Thingswise also provides guidance in overall system design and advanced analytics.

China Academy of Information and Communications Technology (CAICT) contributes to the testbed from standard and security perspectives. CAICT has worked with WPG in building security models, evaluating security risk and helping WPG enable security in end-to-end systems.

Looking back, the testbed appreciates that the IIC ecosystem provides an environment that enables stakeholders to come together, share resources and work cooperatively to achieve common goals.

1. The IIC enables Operational Technologies (OT) and Information Technologies (IT) domain expertise, business models, technology providers and system implementers to come together.
2. The ideas that have been shared and discussed in the IIC, both in technology and business, are very important. The significance of these ideas may go unnoticed at times, but with all of these discussions and presentations, the ideas gradually seep into our mindset, making their way into our business model considerations or technology implementations.

IIC Technical Foundation

The foundational technical documents produced by the IIC have been instrumental in this testbed. The architectures in the testbed are based upon the IIC's Industrial Internet Reference Architecture (IIRA). Since the approval of this testbed, other IIC frameworks have been in development or released, such as the Industrial Internet Connectivity Framework (IICF). They too provide good guidance in designing the testbed system.

Security is complex and of the utmost importance when it comes to systems involving essential infrastructure such as water supply. As the system matures, commands may be issued to the system, especially during diagnostics or repair work. An intruder who penetrates the system in the cloud would have an opportunity to affect large areas of the water supply operations, including interruption of service or damage of the equipment. On the other hand, an intruder who penetrates a pump would be able to inject falsified data into the network about water quality or usage. The testbed works on how to prevent the system from being penetrated and in the event of penetration, how to limit the impact of the actions an intruder may perform. The IIC's Industrial Internet Security Framework (IISF) has been essential, in terms of analyzing security requirements, assessing threats and building security models to prevent the threats.

Role of Standards

When connecting to heterogeneous

equipment built from various manufacturers over a long span of time, interoperability is a big challenge and standardization is clearly important. Learning from this testbed in this area provides valuable input as WPG works in a number of standards in the water supply industrial vertical in China, as one of leading contributors.

Because we cannot afford to wait for standards to be implemented and replace all of the equipment before implementing IIoT systems, it is essential to be able to adapt to the existing equipment that has already been installed. The testbed provides a flexible data adaptation layer to transform data so analytics can be performed in a normalized format.

TESTBED OUTCOMES

From the use case perspective, the testbed plan is divided into 5 stages. After establishing the system and connectivity to the equipment, the first stage seeks to monitor the operational state of the equipment, then to identify anomalies and perform diagnostics. In the second stage, the testbed moves toward predictive maintenance. The third phase involves water quality monitoring and analytics. The fourth stage focuses on stored water quality improvement and balancing the water demand and supply. The fifth stage looks at the overall business model.

Across industry sectors, predictive maintenance has been considered the key IIoT application. However, visibility into the operation states of the remote equipment, e.g. if and how well they are working, already offers value to the operators. With remote monitoring capability, for example, manual on-site inspections can be reduced with substantial savings in human resources.

To be successful in analytics, enough data must be accumulated so that reliable models can be built to establish the operational norms from which anomalies can be detected, faults diagnosed and finally predicted. Root cause analysis and recommended repair procedures are also included as a part of the work flow. Predictive maintenance is still at a very early state because large amounts of data must be collected to enable reliable model building. The testbed is exploring building machine learning models to identify machine running states and anomalies.

Progress has been made in monitoring equipment energy efficiency, currently on a pump-by-pump basis. The next step is to compare it to their peers' normalized usage patterns when a sufficient number of pumps are connected. The goal is to increase energy savings by 30% from the current baseline.

The testbed has connected to a number of pumps equipped with water quality monitoring capability. It is able to monitor quality measurement and receive an alert if the quality is degraded. At this time, the testbed does not yet have instrumentation broad enough to enable model-building to infer water quality across a network.

Based on feedback from the customers, the testbed has been working in a number of areas that are not explicitly outlined in the testbed proposal however are found to be valuable to the customers. These include features to:

- Enhance the visibility to the operational states of the pump, allowing the drilling down to the details of any pumps that have been connected in a digital twin model
- Provide product lifecycle estimates
- Provide pump room video surveillance and access control
- Optimize maintenance and repair workflow by adding a capability to a maintenance mobile app to view real time data from the pump even before arriving the pump rooms.

LESSONS LEARNED

One challenge the testbed has faced is interoperability - how to connect to the heterogeneous pumps made by various vendors, not just those by WPG, that have been deployed over decades. Even for the same model of pumps equipped with the same model of PLC, the data stored in the PLC could vary. The ability to adapt to various data formats is important. Sometime it may be necessary to swap out the old controllers from those pumps to enable the connection to them. Combined with other capability upgrades, this can generate revenues by adapting or transforming old equipment to new technologies.

There is also the issue of establishing communication from the IoT gateways that are connected to the pumps to the system in the cloud. Pumps are usually deployed in basements where the wireless signal is weak if not completely unavailable. Therefore, arrangements must be made with property management companies to enable wired connectivity. There is also the question of paying for the connectivity in the business model.

As the connectivity and data interoperability issues are being solved, a third challenge lies in data analytics. To effectively analyze the data, it requires large amount of quality data to build models. It also needs a close collaboration between the OT and IT sides. Even when quality data have been accumulated, it is necessary not only to identify patterns in the data but also understand what those patterns mean – the latter can only come from the OT side as well. More specifically, one needs to apply OT domain knowledge to the equipment data by applying 'labels' to the patterns identified in them and use that to build machine learning models. This in a sense requires a close-loop of the data lifecycle and closely integrated systems where equipment maintenance and repair records can be correlated with the machine operational data.

Another interesting point to bring up is that through the customer engagement in the implementation of the testbed, the team has also learned the features the customers would be interested in, not just those planned out by the testbed. For example, providing visibility to the remote assets offers substantial initial value. The ability to adapt to the customer's need is clearly important. The testbed is able to do that by reprioritizing the feature deliveries in order to deliver the best value to the customers.

All in all, connectivity to equipment and collecting data are what we usually first focus on in an IIoT project. However, we need to have a longer term vision of how to ensure data quality and completeness of the data collection, and a framework to link operational records and apply OT domain knowledge in the analytic model-building process. Very often, one can collect large amount of data about the normal operational states of the equipment. However, equipment data containing patterns associated with anomalies and faults are equally, if not more, important and these are harder to come by. Therefore, it is important to start IIoT projects early and have a systematic way to collect and manage data so useful analytics models can be built. On the other hand, it is impractical to expect that analytics be perfect from the first day it is deployed. Just like any other intelligent systems, it will take time to evolve and it is a process of continuing improvement.

Biggest Surprise

The biggest surprise was not on the technology side, but on the business side: To see so many potential customers willing to sign up to be part of this IIoT initiative. That experience is unique to this testbed because usually there are challenges getting people to adopt and experiment in the early phases of major new technologies.

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