Vortex DDS Whitepaper

Simplifying Real-time Information Integration in Industrial Internet of Things (IIoT) Control Systems

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1. Introduction

There has been a lot of discussion recently on the technologies and standards that will be used to build the next generation of Industrial Internet of Things (IIoT) systems. Much of the commentary has focused on the protocols and messaging technologies that are proposed as possible solutions to the communication and integration challenges faced by a much more highly connected industrial and business critical application landscape. Within this discussion vast energy from the vendor community, technology commentators and even the standards bodies have focused on identifying and promoting the “silver bullet” protocol for the IIoT in an environment where a range of possible candidates exist. In reality for real-world IIoT systems the solutions being deployed are much more nuanced and inevitably include a number of different protocols providing different capabilities at different layers in the system architecture, both for legacy reasons but also because technically it makes sense to do so.

This paper provides an architectural perspective on where one of the key protocols proposed for use in IIoT systems, the Object Management Group’s (OMG) Data Distribution Service (DDS) Standard, is being successfully deployed to provide machine to machine (M2M) real-time data sharing and integration in complex IIoT systems.

2. IoT and the Industrial Internet

The IIoT is an important part of the wider IoT that targets industrial and business critical systems composed of thousands of sensor enabled devices connected over real-time M2M networks. The Industrial Internet can be viewed as the connection of machine sensors and actuators to local processing and to the Internet. In many cases this involves onward connection to other important networks of machines and people that can independently generate value. The IIoT represents a convergence between machines, low cost embedded sensing technologies, advanced analytics software and Internet connectivity.

The growing proliferation of smart connected intelligent devices is driving the Industrial Internet. This in turn is enabling business to harness the ever-increasing amounts of device generated data, process the data in real-time and act on events as quickly as they occur to drive smarter decisions, enable new services, create new revenue streams and reduce costs.

Computerized machine and process control in a distributed environment is nothing new although historically these systems have relied on centralized management systems. However, with the availability of both centralized and edge-based or distributed information management systems combined with the ability to integrate the capabilities of a number of previously autonomous devices using IP network technologies, this is driving a whole world of new opportunities for industrial devices to collaborate and coordinate their activities, to improve efficiency, support new process models and enable businesses to generate value.

This revolution is naturally driving the need for much tighter integration between Information Technologies (IT) and Operational Technologies (OT). To do this as efficiently as possible the use of both existing and potential new standards to facilitate much greater levels of interoperability between systems and systems-of-systems will be required otherwise integration costs will balloon.

Other key factors for the successful implementation of this new generation of IIoT systems will include the use of Internet connectivity, local data access, the support for distributed information processing combined with advanced analytics, advanced network management and an end-to-end approach to security.

Figure 1 – Access to Real-time Information is Critical in IIoT

In IIoT application domains such as smart power grids or other types of large scale utility management system the integration of the different operational systems has traditionally been via back office centralized management infrastructure. Traditional utilities technologies and their data are often siloed and based on proprietary hardware from different vendors, using many different protocols, software and telecommunication technologies to make the data available to the centralized information systems.

The next generation of industrial systems will need to adopt new approaches to the integration of distributed devices and equipment from many different manufacturers to realize operational benefits. In the power sector for example, existing systems that were designed to support a small number of large generation facilities will be faced with the need to integrate an increasing number of distributed energy resources (DERs), such as wind, solar and electricity storage into existing power generation and distribution networks.

The IIoT offers the potential for industry to move from siloed, single function and proprietary centralized managed systems to new multi-function distributed systems with fully integrated co-ordination with the centralized systems.

3. IIoT Real-time Data Integration Challenge

In order to leverage the expected benefits that the IIoT will deliver to industry, particularly to the operational efficiency of systems, IIoT software architectures must be designed that can leverage the large volumes of actionable data from both the new generation of smart machines / devices and legacy equipment.

This will require a layered architecture, built using a range of software, network and telecommunication technologies. The heterogeneity of devices, machines and systems already deployed using different software stacks and a plethora of communication protocols, will require the use of new interoperable technologies and an architecture that can support the unification of the legacy protocols. This can be achieved by the means of a new generation of sophisticated protocol bridges that can translate device data produced in different formats into a unified representation that can processed by the distributed control systems. The resulting data / decisions produced as the output of this analysis can be shared in real-time across device Local Area Networks (LANs) and the centralized control systems.

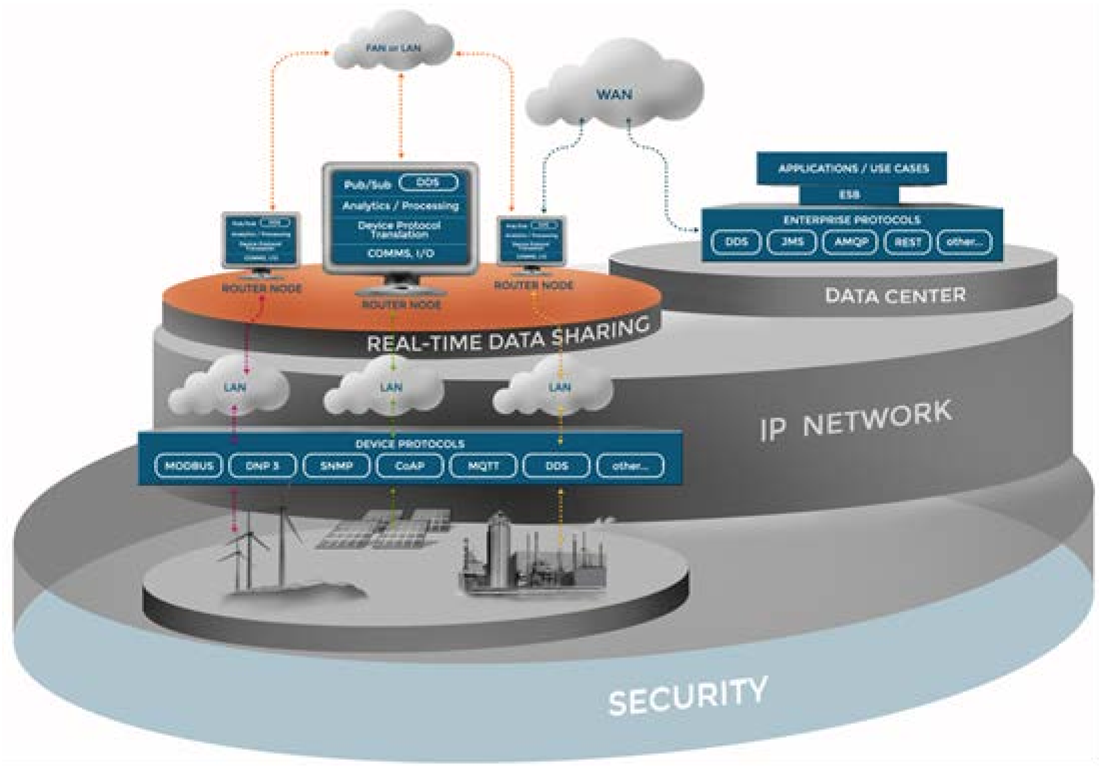

Figure 2 – Layered IIoT System Architecture

DDS implementations, including ADLINK's Vortex DDS Intelligent Data Sharing platform, are already being used very successfully in this scenario to provide a high performance, fault tolerant, secure, real-time interoperable data sharing layer. DDS can be used to unify M2M co-ordination for the edge device networks while at the same time making important real-time data available to the centralized systems, as well as feeding centralized control decisions back down to the devices. The ability to process data at the edge and share control decisions in real-time across device networks that were previously isolated from each other, in a coordinated way, is where the real value of the IIoT is being gained and DDS is a key enabler of this capability. As illustrated in Figure 2, DDS can also be used to send and receive data from the actual devices themselves and in this case no protocol translation is required at the router nodes and data can be shared directly with other nodes, reducing communication latency and improving system responsiveness and performance.

At the highest level of the architecture are the data centers hosting the centralized information management systems. These systems use a different set of enterprise computing and software technologies to support the applications running at this layer. In order to leverage the new flows of real-time device data propagated upwards from the equipment, the centralized systems need to connect into the real-time information feeds from the layers below. In most cases this requires connectivity over a Wide Area Network (WAN). Protocol translation is typically required again to share data from the DDS real-time data feeds and forward the information to the applications using an Enterprise Service Bus (ESB) for processing and possibly offline storage. Centralized control decisions will also flow back down to device networks via the DDS real-time data sharing layer. If the applications are already using DDS as part of their enterprise infrastructure then no protocol translation will be required and additional performance benefits realized.

4. Why DDS for IIoT Systems?

DDS was originally developed for aerospace and defense applications and has been used successfully for many years in large scale, real-time distributed systems. In recent years it has been used in other commercial application domains such as power grid management, industrial automation, transportation management, smart cities and healthcare.

DDS is based on a data centric publish and subscribe model and enables large numbers of distributed applications to share information with each other asynchronously and in real-time.

DDS is unique in its support for the non-functional aspects of data distribution that it can control through a comprehensive Qualities-of-Service (QoS) framework. Over 20 configurable policies can be used to control aspects of data communications such as reliability, priority, importance and persistence to ensure that the data can always be delivered to the right place at the right time, a critical requirement of IIoT systems.

The rich set of QoS provided by DDS enables users to tune the communication behavior of the system intelligently to meet specific requirements. These include being able to specify how long data is available for future use, whether data exchanges are reliable or best effort, the ordering of data presented to an application and whether the data is exchanged as part of a wider transactional context.

Filtering based on content also supports the idea of intelligent data sharing and ensures that applications receive only the data that they are specifically interested in. This frees a subscribing application from performing complex sorting algorithms in order to access information of interest. DDS helps enable complex distributed industrial systems to scale reliably. Scalability is increased due to support for multiple independent data channels. This allows nodes to subscribe to many similar data streams (possibly thousands) with a single subscription. When the data arrives, DDS can sort it and deliver it efficiently. DDS has an in-built state-propagation model, so when treating data structures with values which only change occasionally, they will be transmitted only once for every update, helping reduce network load.

The DDS standard defines a Data Centric Publish Subscribe (DCPS) layer providing a set of APIs and programming language specific mappings. These APIs have been implemented in a range of different programming languages including Ada, C, C++, C#, Java, Scala, Lua, and Ruby. Using standardized APIs helps ensure that DDS applications can be ported easily between different vendor's implementations.

The DDS standard also defines a wire protocol, the DDS Interoperability Wire Protocol, referred to as DDSI. DDSI was designed for real-time systems and is a binary protocol with a very efficient and compact encoding that enables different DDS implementations to interoperate with each other, helping to reduce system integration and costs, as well as preventing vendor "lock in".

DDS also supports automatic "Discovery" that allows DDS nodes to declare the information that they can provide or what data they would like to receive. The protocol will automatically connect appropriate publishers to subscribers for direct peer-to-peer communications without the need for intermediary components such as a broker. This significantly simplifies the process of configuring systems with many devices exchanging data. It also enables Industrial Internet systems to evolve more easily by providing plug-and-play support for devices joining the network at a point in the future. This capability can have significant benefits for large complex IIoT projects, enabling the systems to evolve dynamically and efficiently and minimizing integration costs.

In order to build a trusted IIoT system DDS provides a standardized security architecture that allows applications to protect their communications, manage authentication and access control to resources in systems that may consist of thousands of devices, ensuring the integrity and confidentiality of the data in the system.

5. Vortex DDS: The State of the Art in Data Sharing and Integration

ADLINK has developed the Vortex DDS Intelligent Data Sharing Platform, based on the DDS standard, to support the real-time data sharing needs of complex IIoT systems. Consisting of the Vortex DDS Device and Vortex Link.

Vortex DDS Device enables applications to securely share real-time data using a variety of platform and network technologies. This includes the ability to support data sharing between devices (device-to-device) on the same LAN and data sharing between devices and a cloud-based data center (device-to-cloud). Vortex DDS Device also includes interoperable data sharing technologies that can support a broad range of server, sensor, web and mobile / handheld platforms. Vortex DDS Device includes a suite of advanced tooling that helps IIoT system developers design, develop, test, debug, tune and then monitor and manage Vortex DDS systems and systems of systems.

Vortex Link extends the capabilities of Vortex DDS Device with support for data sharing over a WAN. This includes being able to share data seamlessly between applications running on different LANs via the Internet. Vortex Link can be used with Private, Public and Hybrid Cloud infrastructures.

The Vortex DDS platform provides a rich and open API for integration with both edge based OT development technologies and enterprise IT technologies (such as IDEs, Java EE application servers, M2M platforms and analytics engines).

6. Conclusion

The deployment of both centralized and edge based distributed management systems are opening up a whole new world of opportunities for improved efficiency, new business models and value creation for industrial systems. This in turn is driving the need for a tighter integration between IT and OT. Implementations of the DDS standard are being used successfully to provide a unified integration and real-time data sharing layer between the device networks, distributed processing nodes and centralized information management systems.

ADLINK's Vortex DDS is an advanced suite of technologies based on the DDS standard providing device-to-device and device-to-cloud support for IIoT systems requiring high performance, secure, reliable and interoperable real-time data sharing.

7. About ADLINK

ADLINK's customers build system solutions for the Internet of Things, the Industrial Internet and advanced wireless communications. ADLINK supplies the software platforms, tools and services they need to deliver the performance, scalability, efficiency, flexibility and robustness they require.

ADLINK utilizes industry standards, open source licensing and product excellence to deliver both performance and cost advantages for our customers. ADLINK operates globally and has an extensive portfolio of technology, geographical and vertical domain partners.

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