Vortex DDS Medical Whitepaper

Using DDS for Scalable, High Performance, Real-time Data Sharing Between Medical Devices in Next Generation Healthcare System

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2019

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1. Introduction

Huge advances in medical devices, especially connected and mobile devices, are being driven by the need to provide greater access to healthcare services, offer greater convenience to both patients & clinicians, and most importantly reduce healthcare costs. Using medical devices that are connected remotely requires fewer doctors who can serve more people with greater efficiency. The proliferation of smart connected medical devices is creating a new set of challenges with respect to how networks of devices are integrated together and how they can support the goal of interoperable real-time data sharing.

This document discusses how the OMG's Data Distribution Service (DDS) for Real-Time Systems standard is being used to support the real-time data sharing and device interoperability requirements of modern healthcare systems.

2. Challenges in Healthcare Informatics

The secure transfer of real-time data between medical devices, such as a patient monitor and other information systems, is critical in a clinical environment. Connecting medical devices over a computer network (which can be wired, wireless or mobile) can eliminate the need for manual data entry and the potential benefits include faster and more frequent updates, diminished human error and improved workflow.

Healthcare systems will typically use medical devices supplied by a variety of vendors. Achieving interoperability between devices and other systems is a major challenge as different devices may use different communication protocols and proprietary data formats. Achieving the goal of plug-and-play for medical devices is still some way off and typically custom engineering solutions are required to support special interfaces to enable device data to flow between different vendor's devices and systems. If devices from other vendors are subsequently introduced into the system then additional bespoke interfaces are often required.

Being able to exchange key data from medical devices such as a patient's vital signs, device settings, infusion rates, alarm events and other data sent to and from a medical device plays a critical role in efficiently tracking the state of a patient which in turn can be used to evaluate and plan the most appropriate treatment in order to ensure the best clinical outcome. This also involves evaluating treatment in different clinical environments from the hospital to the home or other care centers. Lack of real-time access or even no access to observational data by clinicians may prevent them from providing their patients with the most effective care.

The key challenges facing the Healthcare Informatics community include:

- Interoperability
    - Between multiple medical devices and information systems, over different network configurations (e.g. LAN or WAN (Internet/Cloud), wired, wireless or mobile)
    - Among multiple healthcare interoperability standards or multiple implementations of the same standard
- Performance
    - Maintaining performance as number of connected devices and information systems increases
    - Low latency data requirements
    - Real-time data sharing and distribution
- Security
    - Confidentiality of patient data
    - Integrity of data exchanged between devices and other systems
    - Authenticity of systems and users accessing medical data
- System evolution
    - Plug-and-play capabilities to allow systems to evolve more easily by adding new devices into the clinical environment
    - Support for fast dynamic discovery of newly connected devices over a network
- Reliability
    - Avoiding single points of failure that can disrupt or compromise data connectivity and patient care

3. Standards and Current Practice

Regulatory organizations and industry initiatives such as Continua Health Alliance (Continua) and Integrating the Healthcare Enterprise (IHE) are working towards standardized vendor neutral device interoperability. Acting as a unifying reference point, the IHE which is an international collaboration of vendors, healthcare providers, regulatory agencies and industry experts is working towards a set of internationally recognized device interoperability standards. The IHE does not develop standards as such but rather develops guidelines or “integration profiles” on how to apply existing standards. The key standards relating to device connectivity and interoperability include, Health Level 7 (HL7), Digital Imaging and Communications in Medicine (DICOM), ISO/IEEE 11073 (Health Informatics, Point-of-care Medical Device Communication) and CEN/TC 251 and ISO/TC 215 (Health Informatics).

Implementers of these standards are free to use a range of different application transport protocols to support device data sharing and message exchanges in a distributed environment. Examples include, Lower Layer Protocol (LLP), Java Message Service (JMS), Java Remote Method Invocation (RMI), Common Object Request Broker Architecture (CORBA), SOAP Simple Object Access Protocol (SOAP), Representational State Transfer (REST) and the Data Distribution Service (DDS). Figure 1 illustrates the communication architecture of a system complying with the HL7 standard using DDS. These protocols are referred to as middleware and can be used to exchange messages/data between devices in a network. The choice of middleware is critical to meeting the requirements of next generation healthcare systems, as not all of these technologies are equal and it is important to consider the capabilities and characteristics of each before basing an implementation on one of them.

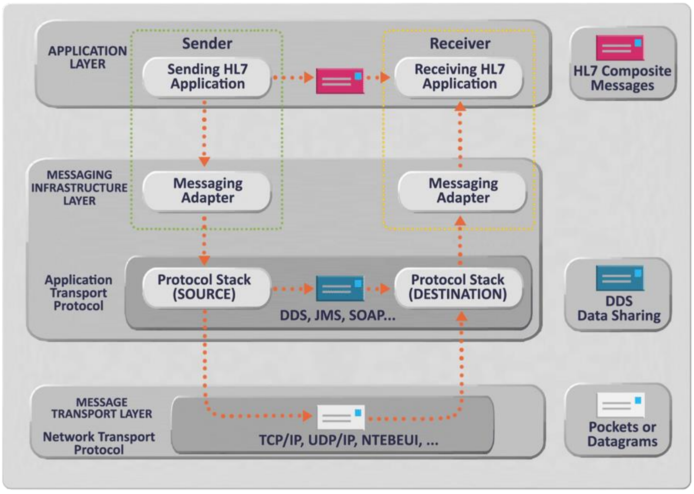

Figure 1 – HL7 Using DDS

4. Medical Device Connectivity Use Cases

With the rapid increase in the variety of devices from different vendors that are being deployed in clinical environments, ubiquitous connectivity and interoperable data sharing are major goals. Developing solutions that can support the following use cases is critical in order to meet the growing challenges faced by the healthcare community:

- Device connectivity and data sharing between medical devices and information systems over a Local Area Network (LAN) e.g. within a hospital or care center. This can be over a wired or wireless LAN
- Device connectivity and data sharing between medical devices and Cloud-based information systems over a Wide Area Network (WAN). For example, a Central Information System hosted on a private Cloud within a hospital receiving device data from a monitor in a patients’ home over the Internet using a wired connection, or a general medical practice accessing a patient’s Electronic Medical Record (EMR) held at the local hospital via an internet connection
- Mobile device connectivity. For example, a hospital information system receiving data from a patient monitor in an ambulance over a mobile wireless 3G or 4G internet connection
- Medical device management, which means being able to remotely connect to a medical device usually by an institution’s clinical engineering or IT departments and accessing technical data from the device in order to locate, troubleshoot or maintain a patient care device

Figure 2 provides an illustration of these key use cases.

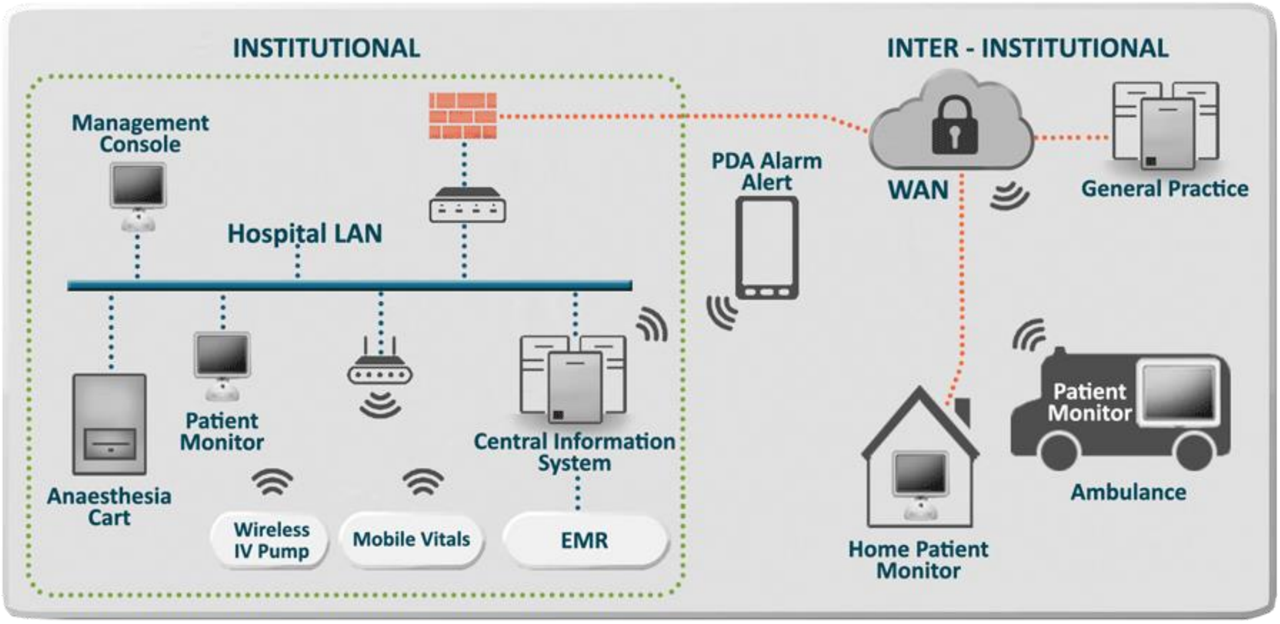

Figure 2 – Ubiquitous Medical Device Connectivity

5. Data Distribution Service for Medical Device Connectivity

The OMG's Data Distribution Service standard specifies a data-centric publish and subscribe model and can enable large numbers of distributed medical devices and other healthcare information systems to communicate with each other asynchronously and in real-time. It also specifies a wire protocol ensuring interoperability amongst DDS implementations from different vendors. Figure 3 illustrates the architecture of DDS.

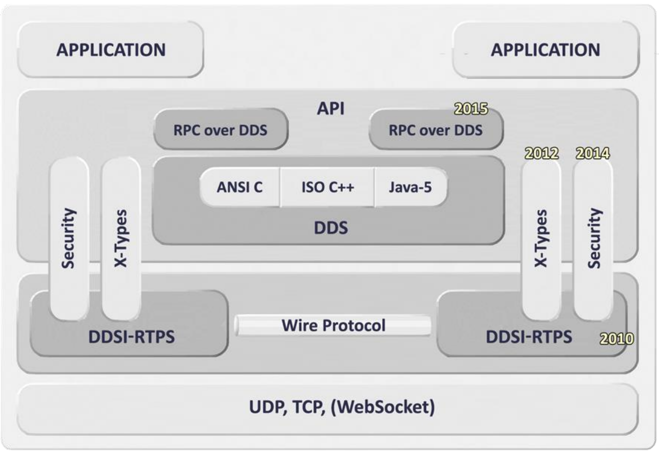

Figure 3 – OMG DDS Architecture

DDS supports data-centric systems where the focus is on the timely availability of real-time information in a distributed environment. DDS implements a 'Global-Data Space' (GDS) as shown in Figure 4 where the unit of information is a sample of a 'topic', a typed data structure accompanied by a set of Quality-of-Service (QoS) profiles specifying the non-functional characteristics of the data. DDS is unique in its coverage of the non-functional aspects of the data that it can control, such as reliability, urgency, importance and persistency. DDS can therefore assure that nodes in a dynamic and distributed environment get a consistent view on the shared data.

DDS specifies communication interactions between publishers and subscribers that are:

- Decoupled in space (nodes can be anywhere)
- Decoupled in time (delivery of data may be immediately after publication or later)
- Decoupled in flow (delivery may be reliable or best effort and with control over available network bandwidth)

These fundamental tenets of the architecture help enable complex medical systems that can scale reliably. Scalability is increased due to the multiple independent data channels identified by "keys". This allows nodes to subscribe to many (maybe thousands) similar data streams with a single subscription. When the data arrives, the middleware can sort it by the key 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 that present a coherent set of standardized "profiles" targeting real-time information-availability for domains ranging from small-scale embedded control systems right up to large-scale enterprise information management systems
- A Real-time Publish Subscribe (RTPS) wire protocol

DDS is both language and OS independent. The DCPS 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. DDS can be deployed on a broad range of Embedded, Mobile, and Enterprise platforms.

DDS also supports automatic "Discovery" that allows DDS participants (e.g. a medical device) to declare the information that they can provide or what data they would like to receive, in terms of topic, type and QoS. The protocol will automatically connect appropriate publishers to subscribers. This significantly simplifies the process of configuring systems with many nodes and many devices exchanging data. It also enables systems to evolve more easily by providing plug-and -play support for devices joining the network at a point in the future.

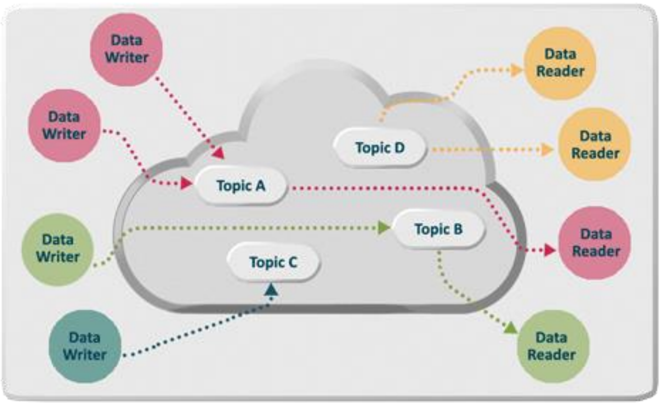

Figure 4 – DDS Global Data Space

DDS supports both unicast and multicasting IP networks to minimize data latency between nodes. It does not require a central server to broker data flows or any other special nodes. In a DDS-based system data communication occurs directly between peers (Peer-to-Peer (P2P)).

DDS also provides WAN connectivity over the Internet. By default, DDS compliant implementations must support UDP as the underlying transport used by the DDSI wire protocol. However, a number of vendors also support DDSI implementations that can also use TCP/IP (e.g. ADLINK's Vortex OpenSplice). DDS has the advantage that it can support low latency data sharing regardless of location. This includes device-to-device data exchanges over the Internet and large fan-outs where one medical device publishes data that is consumed by many subscriber devices or Cloud-based healthcare information systems.

Since its introduction, DDS has enjoyed rapid adoption as a standard for developing and integrating high-performance interoperable real-time systems.

6. ADLINK's Vortex OpenSplice

Vortex OpenSplice is the most advanced, complete, and widely used Open Source DDS implementation. It has been designed to optimally address the real-time information distribution and management challenges posed by traditional high performance real-time data-processing systems as well as next generation big-data systems.

6.1 Vortex OpenSplice Benefits for Medical Device Connectivity

Vortex OpenSplice has a number of unique features that make it ideally suited for use in Healthcare Informatics and specifically to support interoperable medical device connectivity. In particular, Vortex OpenSplice has been designed to offer exceptional scalability and real-time network performance, combined with ubiquitous interoperable device data sharing in heterogeneous networked environments. This includes providing support for wired and wireless LAN and WAN scale networks, including over mobile 3G and 4G connections.

Vortex OpenSplice is the only DDS implementation that gives users the choice of selecting the deployment architecture that best suits them by simply configuring the software at runtime. This allows users to change from a standalone 'single-process' deployment (where the middleware is linked as libraries into your application) to a 'federated' deployment (where multiple applications on a computer share information via shared memory and where network-traffic to/from that federation is arbitrated by a unique network-scheduler based upon urgency & importance of each exchanged piece of information).

The Shared-memory based deployment option shown in Figure 5 features ultra-low latency inter-core communication along with extreme nodal scalability. This architecture results in better scalability, more efficient data-sharing and better peer-to-peer determinism. This is particularly useful to support high performance real-time data sharing between components within a medical device (Intra-device). This differs from other DDS implementations, where library-based deployment prevents nodal arbitration of data-flows and related usage of nodal communication resources.

Vortex OpenSplice' real time networking service allows users to fine-tune, prioritize, and bundle data across topics and applications to ensure optimal throughput, reduce CPU utilization and maximize the use of network bandwidth. OpenSplice RTNetworking provides native real time network-scheduling for deterministic large scale systems. OpenSplice SecureRTNetworking is a secure version of RTNetworking that supports transparent encryption of information in selected partitions. OpenSplice also provides an enhanced version of the core DDSI2 interoperable networking service; Vortex OpenSpliceI2E, offering better determinism, scalability and security enhancements whilst preserving interoperability with other OMG DDSI Rev2.1 implementations.

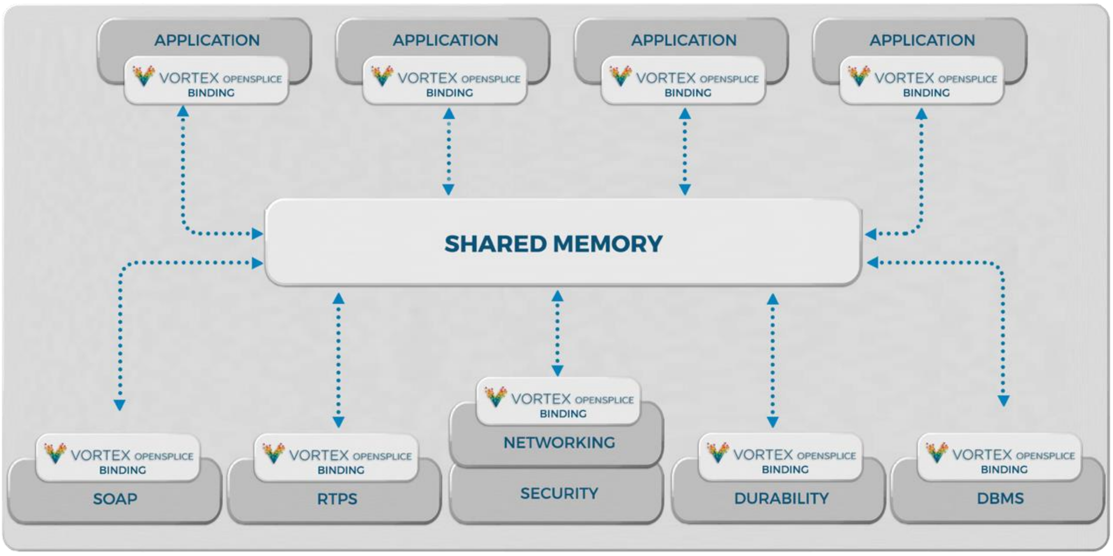

Figure 5 – Vortex OpenSplice Shared Memory and Real-time Networking

The Vortex OpenSplice Tools greatly simplify the modeling, testing, and tuning of DDS-based medical device networks and healthcare systems. They enable total control over a Vortex OpenSplice based distributed environment with support for automated testing and debugging of the system.

6.2 Business Benefits and ROI

Vortex OpenSplice can provide a powerful, high performance infrastructure for interoperable real-time data sharing in healthcare systems composed of both networked medical devices and information systems. In addition to the technical benefits of using Vortex OpenSplice, a number of commercial benefits can also be realized.

The costs to build, maintain, and update a healthcare system that uses Vortex OpenSplice can be reduced by enabling the system to evolve more easily and more dynamically.

A single interoperable communication architecture based on Vortex OpenSplice can be built to support an entire suite of medical devices.

In today's non-DDS-based medical devices, developers often have to create proprietary protocols to support device connectivity and data distribution with adequate scalability and real time network performance. These protocols are costly to develop and costly to maintain. Vortex OpenSplice features such as temporal QoS, data prioritization, and support for unreliable networks have been proven to provide significant scalability and performance benefits for next generation distributed systems.

Vortex OpenSplice Tools for monitoring a DDS-based environment help make it much easier to develop, debug, support and maintain a healthcare system using DDS. For new systems this means being able to be deliver products to market more quickly.

The Vortex OpenSplice licensing model is designed to provide a very sensible reduction of the Total-Cost-of-Ownership (TCO) for customer's middleware infrastructure. This is particularly important in today's market due to the renewed attention to technology expenditure raised by the recent financial crisis and the growing focus on driving down healthcare costs. Traditional software licenses have a very cash-flow unfriendly nature, as they demand the significant investment at the beginning of a projects life-cycle. Vortex OpenSplice subscriptions are cash-flow friendly and ensure customers can exploit the full power of the technology from day one.

ADLINK also provides a wide range of training courses ranging from beginner level up to advanced users. Our trainers and consultants are world-class domain experts and deliver great ROI by ensuring that attendees get an understanding of the technology and how to fully exploit its capabilities.

7. Summary

The need to create more efficient healthcare services and at the same time reduce costs is driving the proliferation of smart connected medical devices. This growth is creating a new set of challenges; including how networks of devices are connected together and how they can support the goal of interoperable real-time data sharing over geographically dispersed heterogeneous networks (e.g. LAN and WAN).

Regulatory organizations and industry initiatives such as the Continua and IHE are working towards standardized vendor neutral device interoperability. Open architecture Standards such as HL7 and ISO/IEEE 11073 have emerged to support the need for interoperable connectivity solutions in device rich clinical environments.

DDS is emerging as an important technology that can be used to address many of the challenges faced by the healthcare community. DDS supports a publish-and-subscribe communication model and importantly was designed to support large scale real-time data sharing. It is already used in many demanding types of mission-critical systems. DDS also defines a wire-protocol so that interoperability between data producers and consumers is guaranteed even if they are based of different vendor implementations.

There is increasing use of DDS in next generation clinical systems to provide interoperability between network enabled smart medical devices and other information systems. With inherent support for plug-and-play, a DDS-based healthcare system can evolve much more easily and at lower cost.

Vortex OpenSplice is the leading Open Source DDS implementation. It provides a fully interoperable solution that has been designed to offer exceptional scalability and real-time network performance. These are all key challenges for next generation healthcare systems. It is field proven and widely deployed in many mission-critical systems. It has a success record of being used in systems ranging from multi-processor single-board computers and mobile devices, to large scale system of systems.

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