Using DDS to Deliver Scalable, High performance, Real-time Data Sharing between Medical Devices in Next Generation Healthcare Systems

Introduction

The Internet of Things (IoT) is set to transform the healthcare sector by lowering costs, improving efficiency, and the quality of patient care. IoT has numerous applications in healthcare from remote clinical monitoring, chronic disease management, preventive care, assisted living, personal fitness monitoring and medical device integration.

The need to create more efficient healthcare services and at the same time reduce costs is driving the proliferation of smart connected IoT 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).

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.

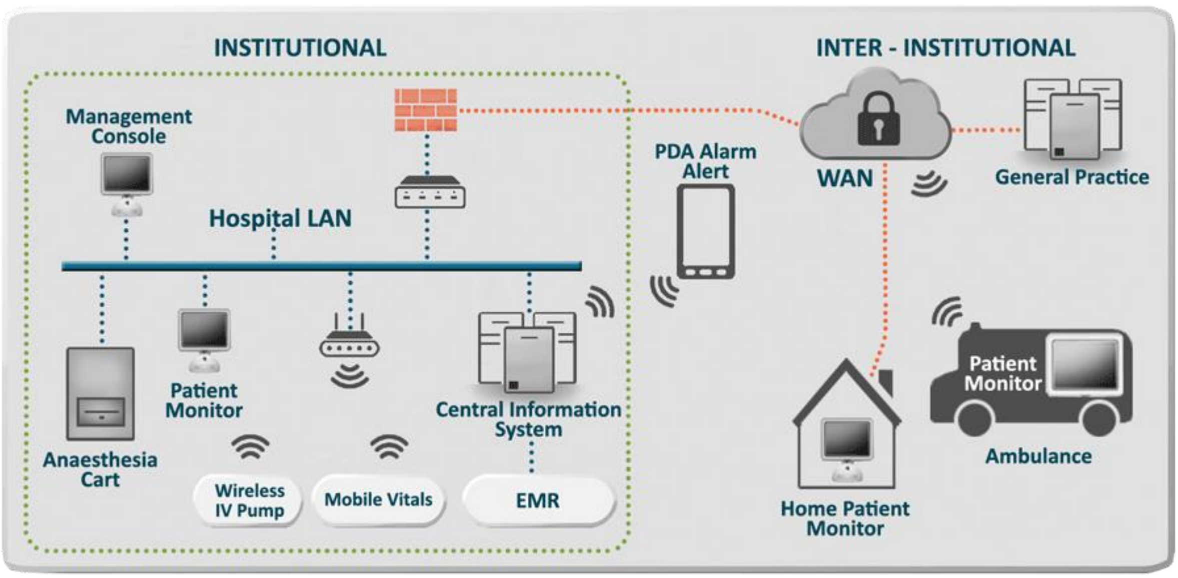

Figure 1 - Ubiquitous Medical Device Connectivity

Challenges

Healthcare systems 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 a 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.

Some of 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 to enable clinicians to view live patient waveform data
- 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

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), SOAP Simple Object Access Protocol (SOAP), Hypertext Transfer Protocol (HTTP), and the Data-Distribution Service (DDS). Figure 2 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.

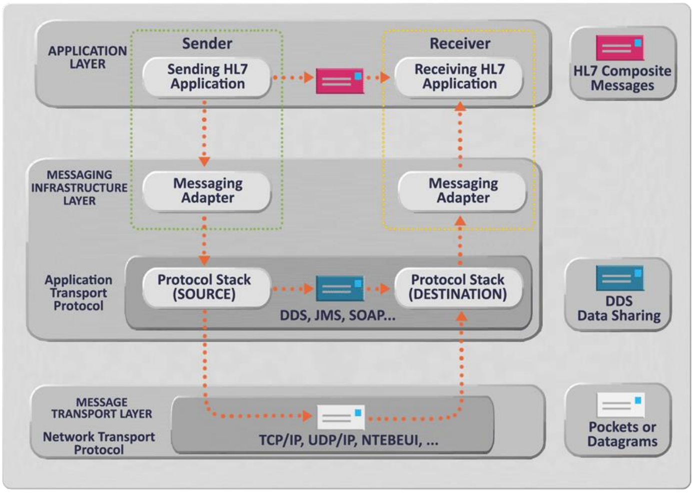

Figure 2 - HL7 Using DDS

Medical Device Connectivity Uses Cases

With the 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, 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

Data-Distribution Service for Medical Device Connectivity

The OMG's DDS standard is emerging as an important IoT technology that can be used to address many of the challenges faced by the healthcare community. DDS supports a data-centric publish and subscribe communication 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. This is makes it an excellent technology to help support the goal of medical device interoperability. Figure 3 illustrates the architecture of DDS.

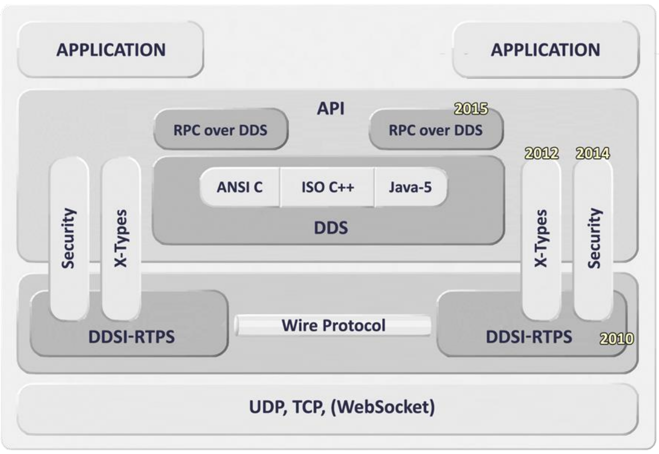

Figure 3 – OMG DDS Architecture

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, persistency and security. 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.

The DDS standard defines:

- A Data Centric Publish and 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
- The Real-time Publish-Subscribe Wire Protocol DDS Interoperability Wire Protocol (DDSI)

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 medical devices exchanging data. It also enables systems to evolve dynamically more by providing plug-and-play support for devices entering and leaving a network at any point in time.

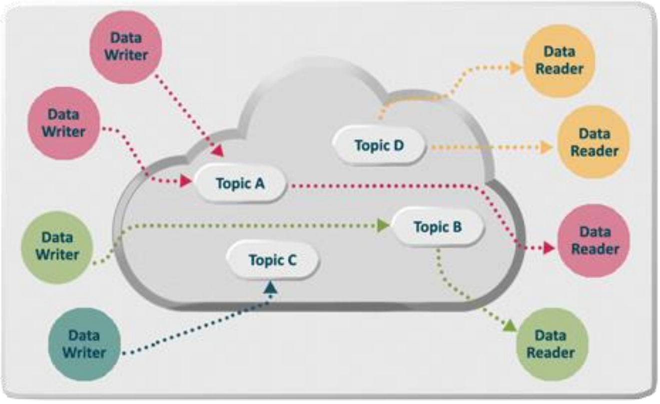

Figure 4 – DDS Global Data Space

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).

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 when exchanging data on a LAN. However, when communicating across a WAN and where UDP is not available, then TCP/IP can be used.

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 where one medical device publishes data that is consumed by other subscriber devices or Cloud-based healthcare information systems.

DSS is supported by a growing and thriving vendor community creating standards compliant implementations. This includes companies such as PrismTech's the creators of Vortex OpenSplice http://www.prismtech.com/vortex/vortex-opensplice, the leading Open Source and commercial DDS implementation. Vortex OpenSplice 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.

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