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An DDS based Architecture in Supporting of Data Centric Wireless Sensor Network Environments

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Abstract

Wireless sensor networks (WSNs) have emerged as one of the most promising technology to provide a wide variety of industrial applications. However, it is still failing to respond in a timely fashion service. In contrast to existing studies, we propose a more practical standard known as Data Distribution Service (DDS), as a middleware standard for interoperable Data Centric Publish-Subscribe (DCPS) architecture with real-time data distribution capabilities, and a candidate for standards based realizations of equally data centric WSN environments. Especially, this paper aims to evaluate on customized design features for real-time WSNs of an applicable and supportive architecture of DDS-based middleware. In the meantime, to integrate the underlying heterogeneous WSN and DDS, a supportive wireless protocol design is required and, thus, those features could be taken into account in designing the protocol.

Keywords: *WSN, DDS, Publisher, Subscriber, Topic*

1. Introduction

WSNs is one of the most rapid growing modern technologies for both industrial applications and mission critical information management [1]. The trend of information distribution of WSN is required to ensure that the right data to the right place at the right time to satisfy Quality-of-Service (QoS) in real-time data distribution system. These information distribution systems in heterogeneous environments drastically run in data centric environments characterized by thousands of platforms, sensors, decision nodes, and computers connected together to distribute information. Eventually, they support sense-making, enable collaborative decision making, and effect changes in the physical environment.

As a middleware, Data Distribution Service (DDS) could be contented the QoS aided accurate data distribution between both the WSNs' inside and outside endpoints [2]. In terms of good matching of data centric modeling techniques in-between WSNs and DDS, the standardization of Object Management Group (OMG) could be effectively utilized. The OMG has created a middleware standard for interoperable, platform independent data centric publish-subscribe architecture with real-time capabilities [3]. A data model can be defined in terms of OMG Interface Description Language (IDL) and related to topics, which can be subscribed by applications. Meanwhile, the API of DDS provides of a rich set of data centric QoS policies.

Nevertheless, DDS was not familiarized for WSNs applications. However, the matching features of DDS have met up several requirements of our proposed WSN middleware. As a DDS domain participant, the Data Centric Publish-Subscribe (DCPS)

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platform is connected with wire protocol Real-Time Publish-Subscribe (RTPS), whose goal is to provide efficient, scalable, predictable, and resource aware data distribution [4]. The RTPS is rooted into large-scale architectures and considers Ethernet-sized network frames and substantial communication resources, and, therefore, its protocol overhead rarely meets WSN requirements. Thus, one of the challenges to overcome for leveraging OMG DDS technology for WSNs is the replacement of RTPS, which is an optional sibling part of the standard. Instead, an alternative approach is required to integrate the extremely resource constraints WSNs environment and DDS with considering some obvious features.

2. Basic Features of DDS

OMG has been introduced to DDS standards which provide a set of features to real-time data centric distribution among the originators and the subscribers. As shown in Figure 1, the OMG DDS specification describes two layers of interfaces:

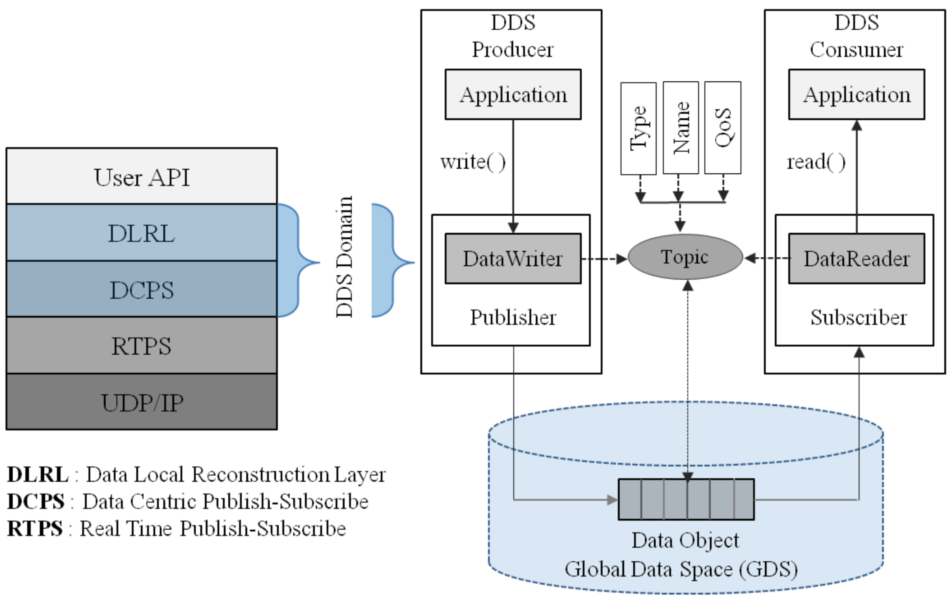

Figure 1. The OMG DDS Architecture for real-time data distribution

The lower layer protocol stack known as DCPS platform provides an efficient, scalable, predictable, and resource aware data distribution. The higher layer, Data Local Reconstruction Layer (DLRL), is an optional platform that provides an object-oriented interface of DCPS and user API. The DLRL extends the DCPS to allow object-oriented information models to specify the information exchange by a DDS application. A separate layer, called RTPS, DDS interoperability wire protocol [5] that defines the standard network protocol in order to distribute data between publishers and subscribers that used a different application of DDS.

The real-time based OMG DDS is a middleware specification which aims to enable scalable, reliable, high performance, real-time and interoperable data exchanges among publishers and subscribers. DDS is designed to address the needs of mission and business-critical applications like financial trading, air traffic control, smart grid management, and other big data applications. There are several entities in the DDS domain as follows;

Domain Participant. Entry point for the communication in a specific domain, it represents the participation of an application in DDS domain. Moreover, it acts as a factory for the design of DDS Publishers, Subscribers, and Topics. Although DDS entities could belong to different domains, only participants within the same domain can communicate, which helps isolate and optimize communication within communities that share common interests.

Global Data Space (GDS). As shown in Figure 1, an intensely typed global data space could be obtained within each domain application which produces and consumes dynamically changing shared information model. DDS's GDS is completely distributed, QoS-aware, and allows anonymous and asynchronous sharing of a common information model. The DDS information exchange model is the only knowledge that publishers and subscribers need to communicate, no need to aware of each other. By allowing data to distribute where and when needed, DDS's GDS enables the sharing of information with satisfying QoS policies.

Topic. A DDS topic is an association between a data type, a set of QoS policies, and a unique name. A topic is also the unit of information contained in DDS's GDS and is used by applications to define their information model and associate QoS policies like Durability_Service, History, Reliability, Destination_Order, Ownership, Transport_Priority, and Resource_Limit with it.

Publishers and Subscribers. The publishers and subscribers of DDS correspond to domain members, ranging from a number of embedded devices, air traffic control radars, visualization consoles, and online stock feed, Micro-Electro Mechanical Systems (MEMS) devices, planning and simulation services operations systems. Information flows with the aid of the following constructs: Publisher and **DataWriter** on the sending side, Subscriber and **DataReader** on the receiving side. So, that, when an application wishes to publish data of a given type, it must create a Publisher and a DataWriter with all the characteristics of the desired publication. Similarly, when an application wishes to receive data of a given type, it must create a Subscriber and a DataReader to define the subscription.

3. The Proposed Architecture

In WSNs, the general routing models like AODV[6], DSR[7], LEACH[8], ECBR[9], etc. are to manage the distributed sensor nodes and route their aggregated data towards the destination/or Base Station (BS). As the BS is/are the strongest platform in terms of power, memory space, and computational capabilities, therefore, we can effectively utilize the DDS features at BS that could be interlinked between heterogeneous WSNs and the OMG standardize other real-time data distribution system DCPS. Thus, the replacement of RTPS could be supportive in terms of utilizing the WSNs' features that can enhance the data distribution among the WSN and DDS enabled other entities.

3.1 The Proposed Architecture

This proposed architecture of using DDS features in WSN is an overall design of DDS middleware implementation to enhancing WSNs application shown in Figure 2. The data distribution operations are defined to naturally adapt the data delivery scenarios of WSNs. Thus, the participants like deploying sensor nodes and BS could be considered as **Domain Participants** of DDS domain. The domain participant acts as a container for all other entity objects. Meanwhile, it acts as a factory for the **Publisher**, **Subscriber**, **Topic**, and a **MultiTopic Entity object**.

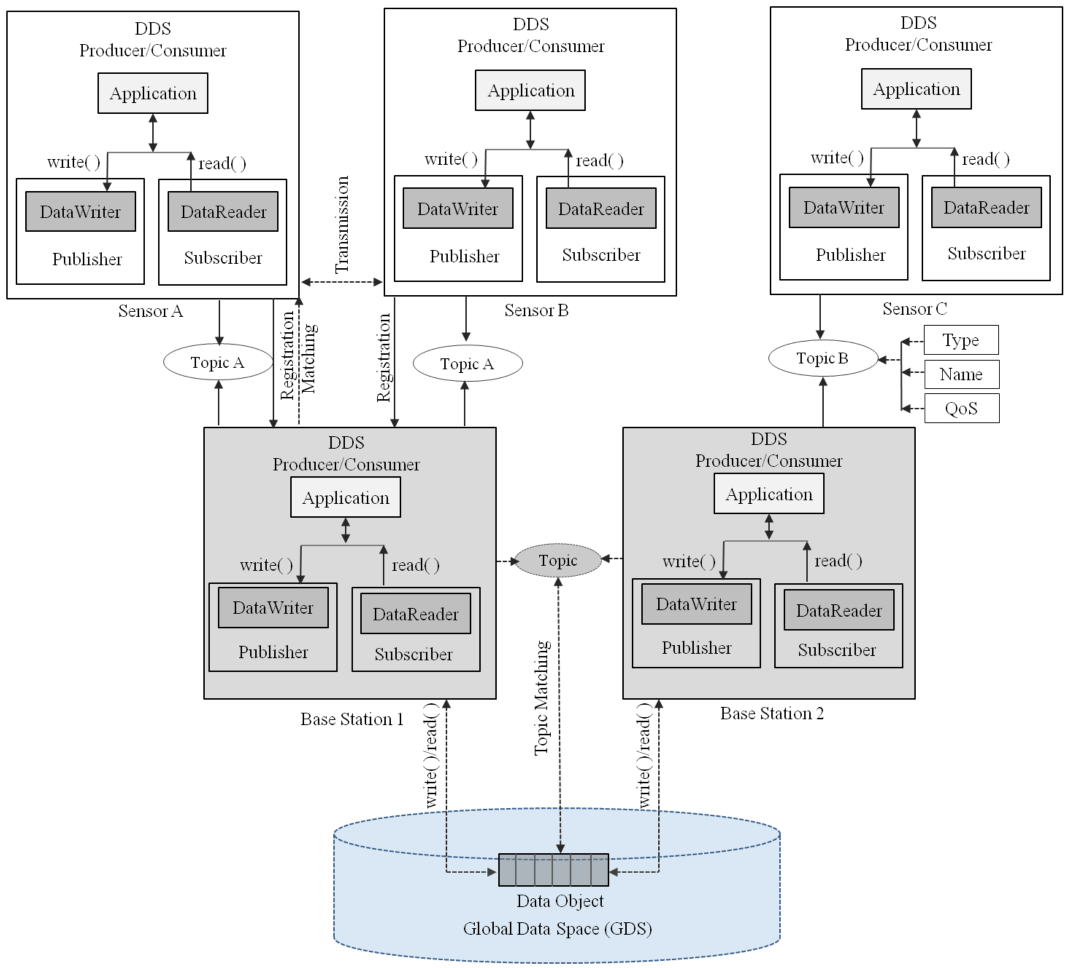

Figure 2. The proposed architecture for DDS middleware implementation in WSN

To enable the standardize service of OMG, the sensor nodes and the BS(s) could be acted as **Publishers** and **Subscribers** simultaneously. On behalf, the BS can serve as a proxy server for a number of deployed sensor nodes in a particular region. For this, each sensor node need to register using the information on their particular **Topic** {Type, Name, QoS} corresponding to their BS and similarly, the BS with GDS in DDS domain and the servers (e.g., proxy server and GDS) save those. When a request for information from subscribers matches a registration from a publisher, the publisher transmits data to the subscriber directly.

3.2 Data Dissemination Sequences

After completion the registration of sensor nodes as well as BS(s), there could be possible combination of data sharing happened among the publishers and subscribers. So, that, the BS could be acted as a key entity to harmonize the publisher and subscriber by working both roles simultaneously. Meanwhile, BS plays a role to interconnect the heterogeneous WNSs and even inside and outside of WSN domains by acting the proxy server between the domains. The operational overview is as follows:

Sensor Node to Sensor Node or Base Station. In order to data sharing between nodes, subscriber (requesting node) sends the request to the proxy server (BS). The server sends the match result to subscriber whether the request matches registration successfully or not. In light of the successful match result of the proxy server, the subscriber sends the request to the publisher (sending node). And then, the publisher provides data for the subscriber. On the application layer, no algorithm is used by server to forward data from the publisher (sensor node) to subscriber (sensor node) as shown in Figure 3. Typically, BS is used for local data storage center among sensor nodes in a particular region in WSNs. For this, BS requires data from the deployed sensor nodes to handle data and further analysis for any applied application. Therefore, in such situation, data are needed from the BS for any sensor node. Thus, when a request for information from the subscriber (sensor node) matches a registration from a publisher (BS), the publisher transmits data to the subscriber directly in a similar fashion.

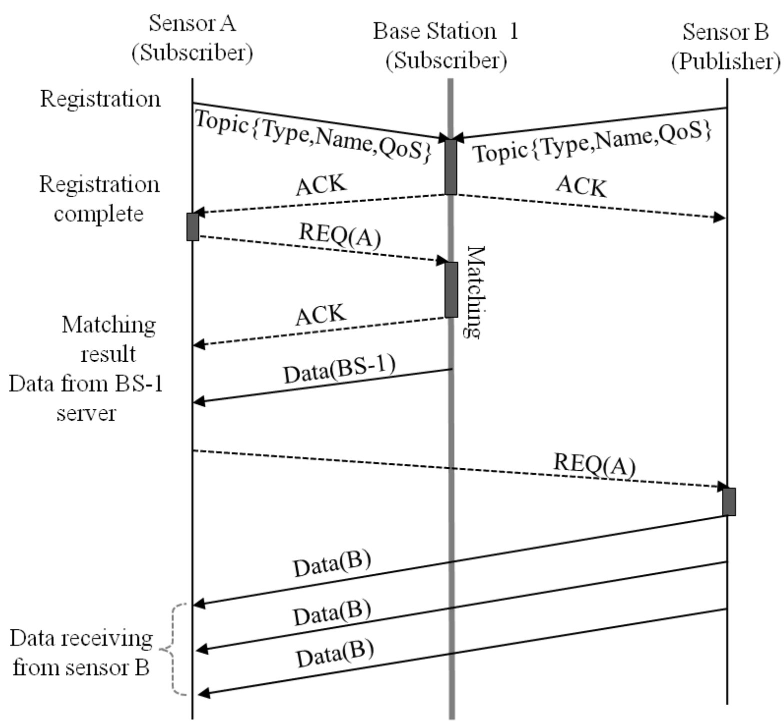

Figure 3. An example of data sharing between sensor nodes and BS

Base Station to Base Station or Global Data Space. To share data between BSs, subscriber (requesting BS) sends the request to the GDS. The GDS sends the match result to subscriber (BS). Whenever the request matches registration successfully with the stored information of BSs, the publisher provides data for the subscriber directly. DDS's GDS enables the sharing of mission critical information and business applicability. For this, data are needed to store at GDS in DDS domain. As DDS's information model capabilities are similar to those of relational database, except that DDS's GDS is completely distributed. In order to store the data at GDS, the matching would be used repeatedly. Figure 4 is shown the data sharing between BS and GDS.

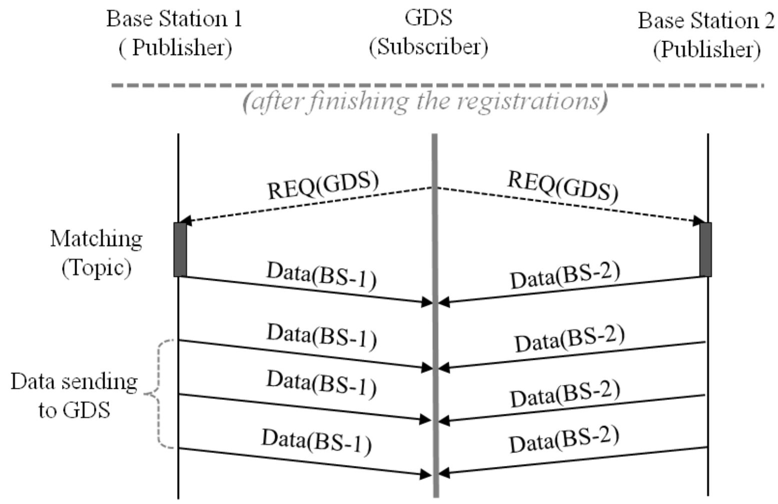

Figure 4. An example of data sharing between BS and GDS

4. Conclusion

The requirement of the OMG DDS certainly matches to WSN architectures which could be beneficial for more standard features. Although the DDS is a potential standard for WSNs set-up, its daemon, using supportive hardware, its involved features are not supported with WSN applications such as RTPS communication wire protocol. Thus, the approach of this paper is to study on designing an applicable architecture of publish-subscribe data sharing middleware that could be connected the heterogeneous WSNs and OMG standardized DDS domain as replacement of RTPS for real-time networking. Meanwhile, to design an applicable wireless protocol which could be supportive to a wide set of underlying heterogeneous WSN with the scalable realization of DDS, some of the features have been suggested on this presented architecture.

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