Modeling RADAR integration using publish-subscribe based middleware

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Abstract

Radars are extremely useful in homeland security for border management and coastal surveillance systems. Due to the terrain, coastal and vegetation conditions a network of short ranged radars are advantageous over single long range radar. Integrating radars in terms of data acquisition and display remains challenging considering the factors like synchronicity, network failures, and channel bandwidth. Publish-subscribe middleware based systems can be used to overcome these difficulties as it provides a decentralized, decoupled and asynchronous communication mechanism.

Keywords: RADAR, DDS, GIS, GPS, Middleware, QoS

I INTRODUCTION

In national coastal surveillance, border management and similar surveillance applications, network of radars is used. An array of radars are being deployed and maintained for this purpose. The radars deployed can be heterogeneous in terms of its type, band and coverage area. The networking of different types of radars adds reliability, fault tolerance and adaptability to the surveillance system. These nodes are placed in a widely distributed geographical location and positional information will be helpful while integrating the information received from radar nodes. Global Positioning System (GPS) device is used to include the positional data in the information which is being sent to the control station. The information is better visualized when displayed on GIS. Global Information System (GIS) provides the map and location information with its enhanced features like terrain, vegetation, road-network, hydrology as layers. The information obtained from the radar nodes are plotted on the maps with respect to the position of the radar nodes. A Common Operating Picture (COP) and situational awareness for an area of operation is automatically obtained in this model.

Every radar node in the networked system has to exchange data, commands and messages. The information generated at each node has to be transmitted in real-time to the centralized Command Control and Display Station (CCDS) for generating the integrated display. A real-time publish-subscribe middleware based information exchange model is well suited for this purpose. In this paper, a concept of integration of radars systems over a Data Distribution Service (DDS) backbone is discussed.

II DATA DISTRIBUTION SERVICE

The Data Distribution Service (DDS) for Real-Time Systems is an Object Management Group (OMG) Publish/Subscribe (P/S) standard that aims to enable scalable, real-time, high performance and interoperable data exchanges between publishers and subscribers. DDS emphasizes on asynchronous, anonymous and asymmetric message communication across heterogeneous distributed nodes or systems. DDS is designed to address the needs of mission- and business-critical applications like air traffic control, smart grid management, sensor network, financial trading, and network management applications. DDS handles all the data transfer chores. It takes care of complex networking functionalities. It implements a publish/subscribe model for sending and receiving data, events, and commands among the nodes. Nodes that are producing information can exchange it with hundreds of nodes at the same time, each one of which can be a publisher, subscriber, or both. DDS takes care of delivering the sample to all subscribers that declare an interest in that topic and with a matching set of QoS with respect to availability, history and reliability.

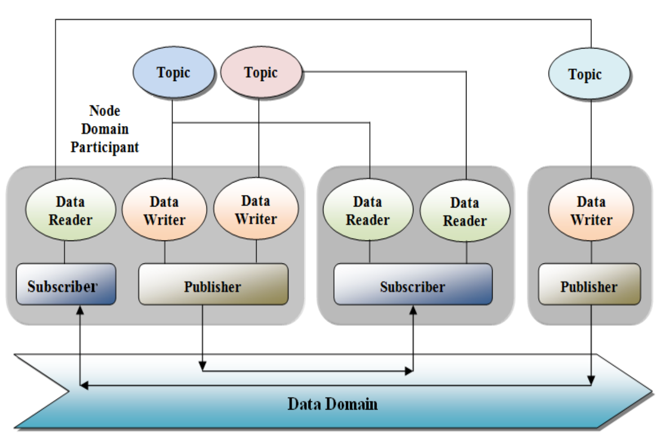

Figure 1 DDS entities

1 *DDS application model*

A DDS application is composed of data providers (publishers) and consumers (subscribers), each potentially on different nodes. Data providers create "topics" (e.g., radar data, temperature, pressure etc.) and publish "samples". Data consumers subscribe to the data. An application may both publish and subscribe as shown in figure 1. A typical DDS application architecture can be represented as a software "data-bus." DDS creates a global shared data-space that greatly simplifies integration. It transmits data directly from a publisher to all its subscribers with no intermediate servers. Publishers and subscribers can join or leave easily, be anywhere, publish at any time, and subscribe to any data. Timing and flow are precisely controlled. Computer platform and language differences are automatically taken care of by the middleware. DDS handles all the data transfer chores: message addressing, data marshalling and de-marshalling, delivery, flow control, retries, etc. By exchanging messages in a completely anonymous manner, DDS greatly simplifies distributed application design and encourages modular, well-structured programs.

2 DDS information model

DDS based architecture is designed on top of four basic building blocks: Information model, Global Data Space, Publisher/Subscriber and QoS. The information model is defined in the form of *Topics*, which define associations between data types, a set of QoS and is identified by a unique name. The data types associated with a topic is specified by means of an IDL (Interface Definition Language). IDL is specified in the form of a structure containing arbitrary number of fields. The fields of the structure define the data items pertaining to a topic that is being published. The publishing of data over DDS and subscription of data from DDS has to match the topic name and the data definition described in the IDL.

3 DDS QoS

QoS (Quality of Service) is a set of characteristics that controls the behavior of the DDS Service. QoS is comprised of individual QoS policies (objects of type deriving from QoS Policy). QoS is associated with all entity objects in the system such as Topic, DataWriter, DataReader, Publisher, Subscriber, and DomainParticipant. DDS has support for 22 different types of QoS policy options. The main QoS parameters are DEADLINE, LIFESPAN, LATENCY_BUDGET, TIME_BASED_FILTER, PRESENTATION, DURABILITY, OWNERSHIP, LIVELINESS, PARTITION, RELIABILITY and DESTINATION_ORDER. DDS gives the ability to control and limit the resources used, automatic discovery of nodes in the network and attempt to repair samples that were not successfully received by reliable data readers using QoS. The publisher and subscriber can able to communicate over a topic only if they agree to a common set of QoS policies.

III PROPOSED MODEL

An integrated Radar system with DDS backbone is proposed in this paper. An IDL representing a "topic" is created which contains predefined information associated with a particular data type. Data writers (DW) and Data Readers (DR) are created on the topic with matching QoS parameters. Applications publish (or subscribe) using these data writers (or data readers) with QoS. Each Radar System (RS) in the network acts as a publisher. The publisher application running in the radar system publishes the target data acquired from the radar along with its geo spatial location, in the format specified by the IDL. The centralized CCDS acts as a subscriber and it has to declare its interest to the DDS domain in receiving data from the radar systems as shown in figure 2. Using the QoS filter mechanism of DDS, CCDS can subscribe to get only the real-time and current data, region of interest, type of target detected, persistence and availability.

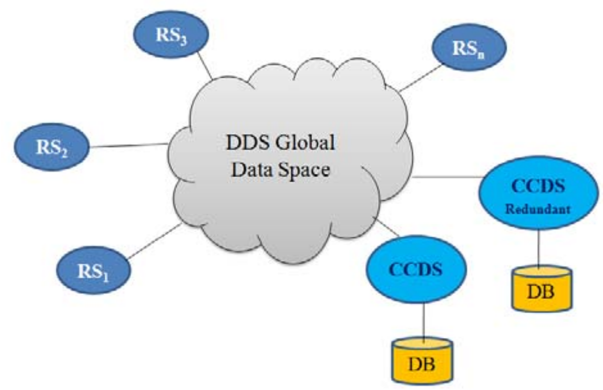

Figure 2 Deployment view of Radar Network using DDS

1 Advantages of using DDS

The advantages of using DDS in the networked Radar systems are:

(i) Real-time *Publish/Subscribe* based mechanism helps naturally the Radar system as the data acquired can be pushed to the display station in real time.

(ii) In case of network failure, the asynchronous nature helps to acquire data even when the nodes are not connected to the server. The radar systems can also be independent.

(iii) Number of Radar nodes in the system may vary according the deployment condition. Due to the flexible and *scalable* architecture of DDS; the applications can be developed independent of the number of nodes.

(iv) CCDS can access the data and represent it visually in many forms due to the access transparency of DDS masking the differences in representation and operation of the invocation mechanisms.

(v) Radar nodes may run in different platform or operating systems and still can communicate and send information to the control and display station.

(vi) The fault-tolerant and redundant implementation of CCDS is easier in DDS as only the subscribe option has to be enabled in the DDS node to acquire data from other radar nodes. As the data is available in the global data space the recovery of services after failure is easier.

(vii) DDS masks the physical locations of the Radar nodes from services. Hence any number of nodes can be added and removed at any time.

(viii) The underlying network in terms of type of network, kind of network and topology of the network can be changed without affecting the existing system. Even over un-reliable wireless networks DDS provides high performance and reliable communications.

(ix) DDS provides a plug & play architecture with dynamic discovery which will be helpful for the radar network as nodes can join and leave without interfering the system.

IV IMPLEMENTATION

A typical implementation with reference to the above model is explained in this section. RS_1 to RS_n refer to the Radar Systems integrated in the network, where '*n*' is any positive integer. CCDS refer to Command Control and Display Station. $CCDS_R$ is a redundant stand-by CCDR station used for fault-tolerance.

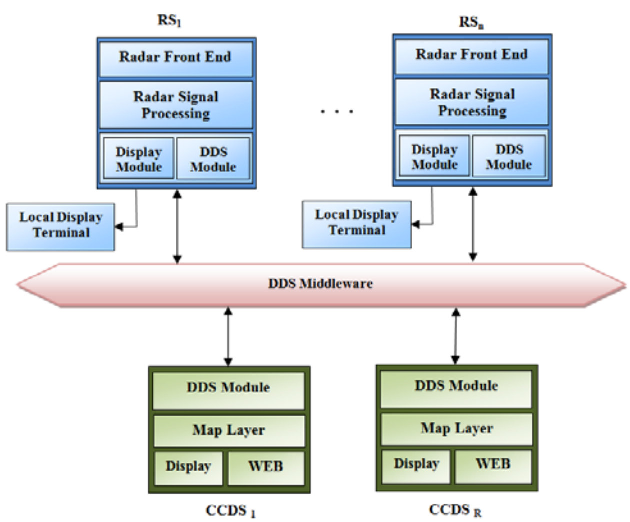

Figure 3 Architecture of Radar Network using DDS

The architecture of the system is shown in the figure 3. RS refers to a Radar System consisting of a Radar front end, Radar Signal Processing Unit, Display module and DDS module. The system may have a local display terminal connected to the display module. Each Radar system has a GPS module also which gives the positional information of the Radar system which will used for geo-tagging the target information obtained from the radar. Synthesized radar data arrives to the DDS module which publishes to the DDS middleware. The DDS module at CCDS subscribes to the radar data topic and receives the data from all the Radar nodes. The data obtained from the subscribers at the CCDS is plotted on the GIS maps with respective geo-tagging. The web server running in the CCDS station publishes the collected information online enabling the remote user to see it on the web browsers.

1 Radar Information model

The radar data is modeled using the DDS information model represented by the IDL. The relevant fields required in the IDL are:

```
Struct radardata
{
        long radar_id;      //radar_id
        long  range;        //range if the target
        long azimuth;       //azimuth of the target
        long elevation;     // elevation of the target
        long velocity;      // velocity of the target
        long intensity;     //intensity information
        long latitude;      //position of LAT
        long longitude      //position of LANG
};
```

The field *radar_id* is a unique id of the radar system from where the data is sent which can be used to uniquely identify the radar system. The fields *range* and *azimuth* represents the range and azimuth of the collected radar data. The field elevation specifies details about the altitude of the target from ground level and velocity refers to the target velocity. *Intensity* refers to the target classification as being strong or weak. *Latitude* and *longitude* represents the latitude and longitude of the radar respectively.

2 QoS settings

Various QoS parameters should be configured for an efficient data delivery in the above model. The RELIABILITY QoS policy controls the level of reliability associated with data dissemination having possible choices of BEST_EFFORT and RELIABLE. This guarantees that the radar data obtained from the radar node is reliably transmitted to the control station. The PARTITION QoS policy controls association between various DDS partitions. It enables grouping of a set of radar nodes to a particular CCDS station. DDS also provides certain QoS parameters for configuring data availability. Durability, Lifespan and History QoS policies allow to control the data availability. The validity of the radar data obtained is crucial for decision making. LIFESPAN QoS policy specifies the maximum time for which the data is valid. The DURABILITY QoS policy provides control over the lifetime of the radar data in the Global Data Space. The HISTORY QoS policy provides a means to control the number of radar data samples stored in the GDS. Possible values are the last, the last n samples, or all the samples.

In radar systems the timeliness of the data is as crucial as availability of the data. DDS provides various QoS parameters to control the timeliness properties of the data: The DEADLINE QoS policy allows application to define the maximum inter arrival time for data. Missed deadline is notified by the DDS to the data reader. The

DESTINATION_ORDER QoS policy controls the order of changes made by publishers to some instance of a given topic. DDS allows the ordering of different samples according to source or destination timestamps. This will provide better target co-relation and helpful in arriving a meaningful conclusion about the target. The TRANSPORT_PRIORITY QoS policy allows applications to control the importance associated with a topic or with a radar topic instance, to prioritize more important data relative to a less important data. Figure 4 shows the data flow between the producers and subscribers on a particular topic "radar data". DDS follows offered vs. requested QoS model for data exchange and the data transfer will start if requested QoS parameters match with offered QoS.

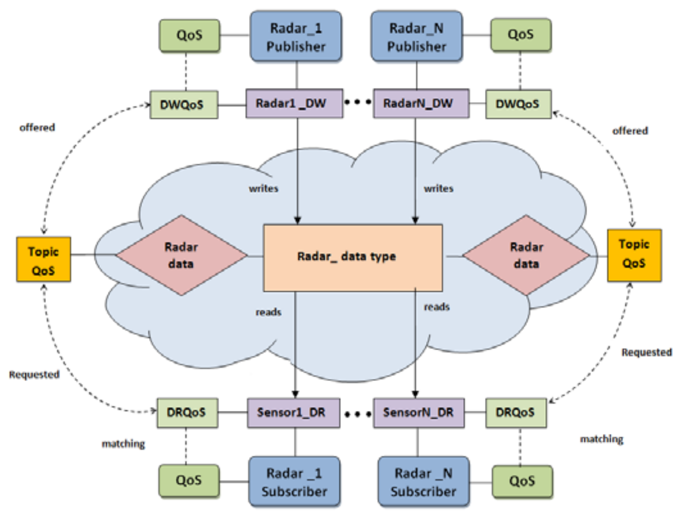

Figure 4 The Radar data exchange between publishers and subscribers

3 CCDS services

CCDS nodes subscribes to the radar data published by the individual radar systems. The geo-tagged data collected from all the nodes are plotted on to the GIS maps in the CCDS's display system. The targets information is provided as separate layers on these maps along with target attributes to get a complete situational awareness. Other GIS information such as weather and climatic condition can also be included on the maps.

Various facilities are provided at the CCDS nodes like Radar data recording, storing and replaying. The data are stored on a persistent local database for future analysis and retrieving.

The system requires information messages to flow from radar nodes to control station and control messages from control station to radar nodes. Using DDS a facility for short messaging is developed, to provide control and feedback information flow between CCDS and radar nodes. Text messaging is provided as a separate topic with attached QoS settings. The facility for generating, sending, receiving, displaying and storing of text messages is included.

V Security

Radar systems need highest level of security and security in DDS based systems is provided at various levels. The security can be incorporated from application, middleware and in network layers. In application the security is incorporated by putting all the publishers and subscribers into a single domain. A domain is a distributed concept that links all the applications that are able to communicate with each other. This prevents unauthorized applications from writing or reading data from the network. Also data pertaining to the IDL only can be written to the GDS. Another method to provide data security in the application level is to put publishers and subscribers on to a particular partition so that only the subscribers in the partition can read the data produced by the publishers in that partition. Partition is a QOS policy provided by the DDS which introduces a logical partition concept inside the physical partition induced by the domain. The partition of the data produced by the publisher can be specified before sending the data over the network. Thus the subscribers belonging to that partition only can receive that data. The security at the middleware level is achieved by building an encryption layer above the communication channel. Every data sample being published is encrypted before it reaches the GDS. The decryption happens at the receiving end. DDS also supports network level security by providing options for enabling TLS (Transport Layer Security) or DTLS (Datagram Transport Layer Security).

VI Conclusion

DDS middleware is well suited for networked radar systems. The process of collecting the radar data from geographically distributed radar systems in real time is simplified by the introduction of DDS. The method of data collection through a real-time publish-subscribe paradigm and representing the radar display on a Geographical Information System (GIS) is described. The DDS technology can be used in Coastal Surveillance Radar for threat perception. Different nodes of radar in coastal areas can instantly transmit data to command centers for efficient decision making and situational awareness. Weather Radar Network is another area where DDS can be incorporated. With use of DDS middleware, information on cyclone detection, storm detection, etc. can be passed to other nodes and information dissemination centers. This will enable the government and local administration for better disaster management and recovery.

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ACKNOWLEDGEMENT

The authors would like to thank Dr. Ajit.T.Kalghatgi, Director (R&D), BEL, for providing opportunity and support to work on DDS in CRL. The authors also thank Mr. Mahesh.V, Chief Scientist, CRL, for encouraging presenting a paper in ISRI 2013.

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