WAN-DDS
A wide area data distribution capability

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Abstract - The publish-subscribe paradigm has shown many qualities to efficiently implement distributed systems. In the era of Global Information Grid, this paradigm can be applied for information sharing across systems and platforms of a maritime coalition. As with CMS, it is especially well suited to support maritime surveillance information flows across platforms. This paper will introduce the concepts and principles of a wide area Data Distribution Service (WAN-DDS) as one essential information dissemination service within the Enterprise Services architecture of the GIG. It will show how the mechanisms of the OMG DDS standard can be extended to a wide-area context, how it can be integrated into a maritime wide area network infrastructure and how it fits in a web services architecture.

Index Terms – publish/subscribe, DDS, wide area, overlay network, web services

I. INTRODUCTION

Interoperability and collaboration in a mobile tactical environment are the pillars for shared, timely and fused awareness of the maritime environment enabling coordination and speed of command. The type of information which needs to be shared, the people with whom it needs to be shared, and the speed with which the information needs to be gathered and made available, is determined by force structures, concepts of operations, and the way the information is utilized to support a mission.

Publish – subscribe data distribution is a proven concept that can provide the right information at the right place and at the right time [1]. Publish – subscribe communication is data centric and enables automatic data processing with minimal dependencies between publishers and subscribers. Publish – subscribe is one of the service interaction models in the Global Information Grid (GIG, [3]). The GIG is taken here as a reference.

There are several publish – subscribe models and technologies available, but the OMG DDS [2] has become popular since it has been released as a standard. Next section will give a short review of the DDS. Then publish – subscribe in the wide area context is discussed and an assessment is given about the DDS in the maritime wide area. As a result of that, the basic principles of a WAN-DDS capability are formulated and the need for an underlying overlay network is discussed. Finally, it is explained how a WAN-DDS fits within a Service Oriented Architecture (SOA).

II. DDS IN A NUTSHELL

The OMG Data Distribution Service (DDS) is a middleware service for data centric, distributed real time systems. The DDS is based on the publish – subscribe paradigm and builds on the concept of a global data space. Publishers write their data into the global data space and the service delivers the data to all interested subscribers and informs the subscribers that new data is available.

The DDS provides for decoupling in space, time and frequency between publishers and subscribers. Publisher and subscriber only share the notion of a common information model. The basic gathering of information is a Topic. A Topic is a structured data type with a (composite) key that identifies the instances of that Topic.

![DDS Global Data Space](image_url)

Figure 1 DDS and the global data space
The DDS specification defines a sophisticated set of so-called Quality of Service Policies (QoS Policies) that enable to tune the DDS with respect to things like transport reliability and transport priority, storage durability and history depth. The DDS is a powerful service that enables to build fault tolerant systems where applications can join and leave the system in an ad-hoc way. The DDS is also very suitable as a common backbone for the integration of different systems.

The initial release of the OMG DDS standard specifies the API enabling the portability of applications between different DDS implementations. Standardization of the interoperability or wire protocol is in progress, enabling the interoperability between applications executing on different DDS implementations.

III. PUBLISH – SUBSCRIBE IN THE WIDE AREA

The DDS has a lot of features that make it of potential interest for use in the Global Information Grid (GIG, [3]). The DDS is data centric; the DDS supports ad-hoc networking and provides for automatic data processing. The DDS is very well suited for one-to-many and many-to-many type of communication.

Collaboration is essential in combined and joint operations. Collaboration is about shared awareness and requires services like application sharing, file sharing, white boarding and teleconferencing (audio and video sharing). The DDS can be positioned as part of the collaboration services in the GIG. The DDS enhances collaboration with a data sharing and data dissemination service and allows for automatic data processing. The DDS is to support capabilities such as distributed tracking, like in ballistic missile defense, and distributed awareness, like in maritime surveillance. Both are examples of many-to-many type of communication.

IV. DDS LIMITATIONS

Although the DDS provides features that are of interest to the GIG, there are also some issues that may limit the acceptance in the GIG. These are:

- The DDS is an extensive specification with a number of features that are not relevant in a wide area context (see below). This makes it less likely that the DDS is available on all relevant user appliances and provider platforms. This is probably also the reason why CORBA and DCOM do not (did not) make it in the GIG, and it may also cause problems in bandwidth-constrained hierarchical RF networks that are typical for maritime wide area networks.

- The current DDS specification is based on IDL. A Topic is defined by means of IDL. This is perfectly well suited for applications that are designed to work together as a system on a LAN. IDL is pre-compiled into the language of choice and is therefore very efficient for real time applications. But in a wide area context this is not sufficient. In a wide area context it is important to provide information about the data, so called metadata. Metadata enables remote users and applications to discover, retrieve and process information in a heterogeneous environment. Metadata can provide information about data schemes hence addressing the problem of different domain data models and the possibility to mediate between the models.
- The DDS deals with structured data only. A publish – subscribe mechanism in the GIG should also be able to deal with unstructured data like images.

Note that despite these limitations it is very well possible that in a closed community with applications designed to work together, the DDS is used in the backbone, assuming that bandwidth is not a constraint. For instance, similar DDS based Combat Management Systems (CMSs) on different naval platforms working together in a task group.

V. WAN-DDS CONCEPTS AND PRINCIPLES

General The OMG DDS specification has been established through a process of consensus resulting in a common multiple set of requirements. For the maritime wide area the approach should be to define a common divisor set of requirements.

The wide area data distribution capability that is described here is called WAN-DDS. WAN-DDS is not an implementation; it is about concepts and principles. WAN-DDS users may be equipped with a local area network (LAN). When DDS is used on the LAN, a gateway can bridge the LAN to the WAN keeping the local DDS applications transparent for the WAN.

Information model Publish – subscribe data distribution requires a common notion of the information that is exchanged. The Command and Control Information Exchange Model (C2IEDM, [4]) is an operational data model that has been derived through consensus. C2IEDM comprises a common vocabulary related to all domains of military operations, including civil – military operations. NATO is also in the process to adopt C2IEDM as a STANAG. C2IEDM is therefore a strong candidate for information exchange between systems in the military wide area.

XML WAN-DDS should be based on the eXtensible Markup Language (XML). XML is a ubiquitous Internet technology that arose from the need to describe data structure, data content, and data transformations in a standard way. XML is also the cornerstone of Service Oriented Architectures (SOA).

Meanwhile there is a rich set of XML related specifications amongst others XSLT for schema translations, XMLNS for namespaces, SOAP for web services and XML Encryption for security. All these specifications are of interest in a wide area context. XML is also the mandatory metadata format in the GIG, and there are already XML schemas available for legacy military data formats like AdatP-3 and OTH-GOLD.

Content-based subscription WAN-DDS should support content-based subscription, where a consumer expresses its interest in a piece of information based on the content of that information. Content-based subscription is a powerful mechanism for consumers, but it also enables to disseminate data in a more selective way.

QoS Policies The OMG DDS defines a large number of features and QoS Policies that enable applications to manipulate the data and to tune the behavior of the service. Not all of these features and QoS Policies are needed or relevant in a wide area context. For instance, the OMG DDS has the notion of a local cache at the subscriber side where data samples are kept. The subscriber can perform operations on the cache like queries, read, take and so on. WAN-DDS does not need to support a local cache. It just delivers the data to the subscriber and the subscriber is responsible for caching the data when needed. This can be realized, for instance, by using a local DDS. QoS Policies that deal with the way...
samples are organized and managed in the cache are therefore not relevant for a WAN-DDS.

The table below lists the OMG DDS QoS Policies that are considered relevant for a WAN-DDS.

<table>
<thead>
<tr>
<th>QoS POLICY</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>Durability</td>
<td>Expresses whether the service should keep samples in memory (transient and transient-local), on disk (persistent) or not at all (volatile).</td>
</tr>
<tr>
<td>Latency budget</td>
<td>Specifies the maximum acceptable transport delay</td>
</tr>
<tr>
<td>Time based filter</td>
<td>Used by a consumer to express that it is only interested in a subset of the updates</td>
</tr>
<tr>
<td>Reliability</td>
<td>Expresses the level of transport reliability (best-effort or reliable)</td>
</tr>
<tr>
<td>Transport priority</td>
<td>Priority indication for the underlying transport services</td>
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Table 1 Applicable QoS Policies

Most of the above QoS Policies deal with the quality of service provided by the underlying transport services. The Durability QoS is an exception. Transient-local means that samples are kept at the producer side. Transient-local is needed to support late joiners. Transient is to out-live a producer and to provide distributed replication. This is a nice to have feature. Distributed persistency is not required as part of a WAN-DDS.

Security WAN-DDS relies primarily on the general security measures that are in place such as network level encryption (IPSEC) and link layer bulk encryption.

VI. OVERLAY NETWORK

The maritime communication architecture consists of shipboard LANs, HF / UHF LOS and BLOS communication, military and commercial satellite communication, trunking and subnet relay. In order to isolate applications like WAN-DDS from this heterogeneous network infrastructure, an overlay network is required that takes care of variations in bandwidth and various types of communication assets and that provides resilience, scalability and survivability. WAN-DDS nodes can be seen as peers within this overlay network.

Figure 4 WAN-DDS with overlay network

Although the focus is on WAN-DDS, the overlay network is in fact a generic capability that can support more types of applications such as multimedia. The overlay network should provide the following features.

Bandwidth Optimization The maritime WAN is composed of a bandwidth-constrained networking infrastructure. Bandwidth optimization is therefore an essential feature to guarantee communication efficiency. Bandwidth optimization can be realized through payload and/or header compression, e.g. xmlzip and ROHC [5].

Multicast Support Multicast is also a way of bandwidth optimization and should therefore be used as much as possible. When multicast is not supported by the underlying networking infrastructure, it has to be provided by the overlay network. In addition, a multicast gateway could be provided that acts as a unicast – multicast bridge.

QoS Management The overlay network should provide the quality of service requested by the WAN-DDS. This comprises transport reliability (also for multicast), message priorities and packaging delays.

Non-IP Networks Although the GIG assumes an all IP communication infrastructure (see Figure 2), non-IP networks are still applicable in the maritime WAN. Support for non-IP networks is therefore nice to have. This requires own addressing and naming schemes and may also include support for the wireless datagram protocol (WDP). WDP equals UDP when an IP-bearer is available.
EMCON Support EMCON or radio silence conditions are often required in tactical maritime communications. EMCON should therefore be supported by a receive-only mode of communication.

Discovery Dynamic discovery of peers is essential in ad-hoc networks and should therefore be supported.

Security The overlay network relies also on the security measures that are in place, including a certification infrastructure for peer authentication.

VII. WAN-DDS AND SERVICE ORIENTED ARCHITECTURE

The GIG initiative, but also other initiatives in this area like NATO Network Enabled Capability (NNEC, [6]) and Maritime Tactical WAN (MTWAN, [7]), emphasize on the use of a Service Oriented Architecture (SOA).

SOA defines a framework where service providers register their service by providing a service description. A service consumer can find a service by querying the registered services. In the bind operation the consumer invokes the service.

WAN-DDS, as a service within the GIG, should provide and register a web service interface. The web service interface enables local and remote SOA applications to bind to the service, to publish information into WAN-DDS, to retrieve information from WAN-DDS, and to set QoS Policies. Using SOA to register, find and bind WAN-DDS publishers and subscribers does not make much sense, because that is implicitly performed by WAN-DDS.

VIII. CONCLUSIONS

The publish – subscribe paradigm in general, and the OMG DDS in particular has valuable features for use in the GIG. The OMG DDS is data centric, supports ad-hoc networking, enables automatic data processing and provides adaptability through QoS Policies. But it has some drawbacks that may limit the acceptance and deployment within the GIG. The OMG DDS is rather heavy and lacks support for XML, which is the cornerstone of Service Oriented Architectures. The principles and concepts of a wide area data distribution capability, called WAN-DDS, have been presented and the need for an overlay network has been discussed.

WAN-DDS is just a concept. Next step is the realization.