Experiences from Knowledge Gathering and Formalisation during Development of Air Defence Systems

Andrzej Walczak, Stanisław Trytek
Przemysłowy Instytut Telekomunikacji S.A.
Poligonowa 30, 04-051 Warszawa,
POLAND
awalczak, tryteks@pit.edu.pl

ABSTRACT

In this article we present evolution of object-oriented models used for gathering knowledge about tactical situation. Short descriptions of "OP-NET" network and "TacticalEntity" models used in C2 Real-Time domain are presented. Development of "OP-NET" network integrating elements such as: radar systems, CRCs, SAMOCs, airfields shows that modelling information domains is very needful in order to assure proper information transfer without human errors.

Experiments conducted during R&D programmes for Ministry of Science and Higher Education [1,2] *show us that our models allowed us to participate in semantic network experiments learning how to exchange information between systems from various domains.*

1.0 INTRODUCTION

In the aspect of larger scale integration of systems the amount and complexity of information is increasing considerably. The more systems are "talking" with each other the more "languages" they need to operate. This is why knowledge gathering and formalisation aspect is so important during system design. During development of OP-NET and SAMOC such process was carried and cognition was accumulated. Radar data transmission using ASTERIX format, gathering position of weapon systems from MTF messages or LINK communication shows that C2 system requires translation of information from several formats into common knowledge/sense in order to perform C2 system duties such as decision support and increase situation awareness (SA).

The second part of the article presents the concept of the integration approach that supports semantic interoperability in wide spectrum of systems. The approach is based on experiences gained during development of Polish C2 systems and the need of future "systems of systems" integration in the context of NNEC (NATO Network Enabled Capability) doctrine that covers different levels of command, different operational domains - Air, Land and Maritime and different technological domains which are characterized by different time constraints. The integration concept is presented together with experiments proving the applicability of the solution.

[1] O R00 0050 06 (PBR 15-010) - Integracja systemów dowodzenia (2008-2010)

[2] PBZ-MNiSW-DBO-02/I/2007 - Zaawansowane metody i techniki tworzenia świadomosci sytuacyjnej w działaniach sieciocentrycznych, (2007-2010).

2.0 KNOWLEDGE GATHERING DURING ”OP-NET” AND SAMOC DEVELOPMENT

The Air C2 System “DUNAJ” is dedicated to the execution level of Air C2 and consists of four CRCs and several SFPs. All data exchange is performed by Wide Area Network (WAN) called “OP-NET” which provides access to other AirC2 entities such as AOCC, SAMOC, WOC/SQOC. The automated Air Command and Control System (C2) “DUNAJ“ is the backbone of Polish Air Defense System and it is developed as dedicated computer network. ”OP-NET” Wide Area Network has been developed and deployed during the development of the ”DUNAJ” system between 1997-2001 and is designed to provide connectivity between various Air Defence elements on the area of Poland. Figure 1 presents ”OP-NET” network users and in the same time building blocks: data sources(sensors), **C**ommand & **C**ontrol control elements (C2), surveillance elements, weapon systems.

The “OP-NET” WAN consists of set of nodes (called Autonomous WAN Nodes, AWN) connected by means of data communication equipment. WAN covers all Polish territory. Each *A*utonomous *W*an *N*ode (AWN) consists of IP router, LAN switch and computer having capabilities of protocol adaptation and data filtering according to user defined criteria. In the WAN information from sensors, RAP and weapon control information is available. Such composition of system parts provides capability to communicate using INTERNET family protocols. Application of IP/MULTICAST/UDP transmission allows to access each type of the information at each of the nodes of OP-NET network. The “OP-NET” WAN provides also foundation for e-mail exchange and other collaboration services. Based on such architecture the whole system possesses high reliability and backup capability.

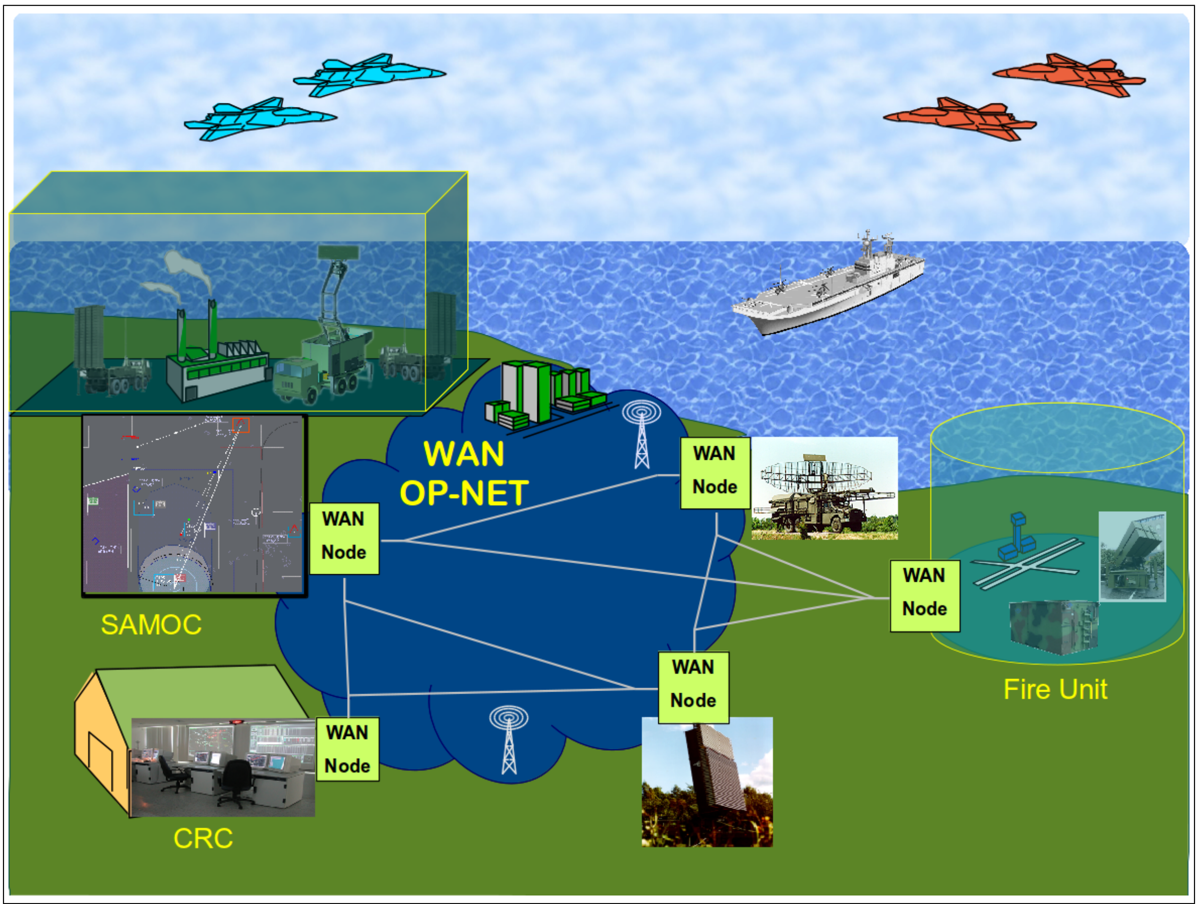

Figure 1: Operational view of ”OP-NET” network environment for data exchange between tactical elements.

As mentioned earlier, ”OP-NET” is a IP based Wide Area Network providing infrastructure such as:

data transport mechanisms, time synchronisation services, reliable group communication, system and network management capabilities. WAN node within this network is an integrator of other elements and access point for data exchange. Some general assumptions about WAN organisation are: all data sources are available in WAN environment; all data processing is conducted by C2 nodes that could be connected to any node of WAN; decision making process is conducted in C2 nodes.

2.1 Integration of information from Real-Time domain and Non Real-Time domain

During the development of Polish SAMOC as the system developers we touched more worlds such as LINK-11B, small scope of LINK-16 and several MTF messages (to name a few: COVREP, ATO, ACO) and relevant orders/reports from Bi-MNC Reporting Directive Vol. III. Integration of information from various sources in order to decrease operator workload is a challenge which brings profits such as increasing level of Situational Awareness (SA) and decreasing probability of human mistake. Research on that area was conducted and documented in [1] and [2].

3.0 KNOWLEDGE GATHERING DURING CREATING ”OP-NET” C2 COMPONENTS

During design of elements for weapon control such as Fire Units and SAMOC several models in UML [3] has been created. Models were developed in Rational Rose tool using IDL plugin (see [4]). Later on those models were integrated to be consistent and provide shared knowledge base for designers. In the ”OP-NET” environment several implementation languages has been used such as: C++, Java and Python. Real-Time CORBA implementation has been selected as the middle-ware together with SPREAD Reliable Group Communication System [5]. In such environment CORBA IDL was selected as the common modelling language for several implementation platforms, and therefore served as PIM. One of the important design decisions worth mentioning is the choice of XDR (see [6]) as the PSM. XDR is used as a presentation layer for messages transported over the Wide Area Network. Choice of XDR has been made as a common denominator across several platforms such as QNX, MS Windows, UNIX. Tools translating IDL into XDR and other formats were developed and are used in the process of software building.

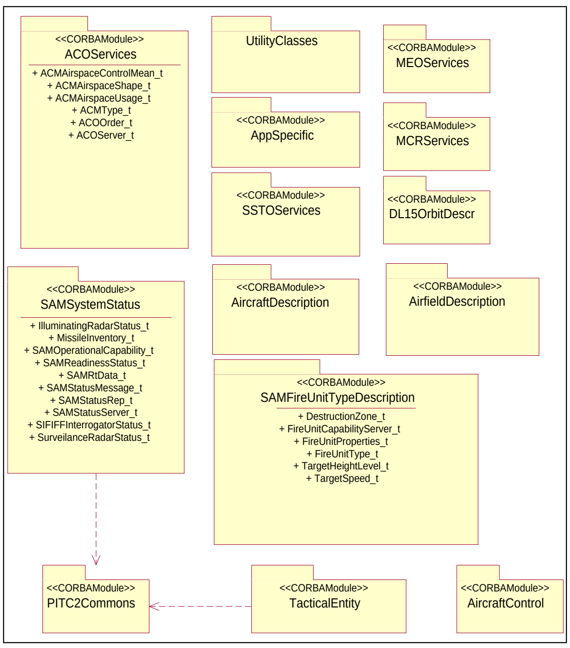

Figure 2: Package diagrams of ”OP-NET” UML model.

Figure 2 presents "OP-NET" UML package diagrams of model used further on during SAMOC development. A good example of sharing knowledge/information is server which provides ACO information.

Later on as a result of R&D works the models were merged and re-engineered to became a "OP-NET" model representing knowledge in the area of surveillance, weapon control and partially of electronic surveillance.

The idea of creating single consistent data model and data exchange rules was to allow creation of well defined borders between "OP-NET" world and for example LINK protocols. Generally speaking, this process is carried on because knowledge about military data links is not only contained in the STANAGs and ADatPs. Further on "OP-NET" model was integrated even more and became known under the name "TacticalEntity".

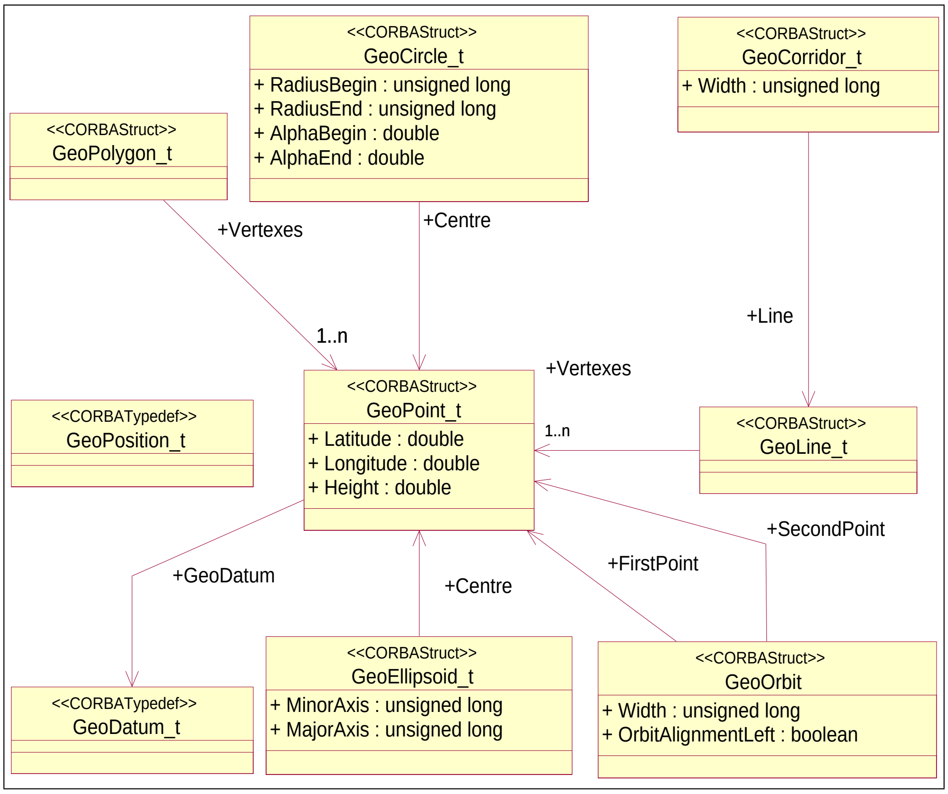

Figure 3: Example of "OP-NET" Geometric Primitives

To present small a example of evolution we would like to show a limited part of the model as an example of evolution between "OP-NET" model and "TacticalEntity" model. Figure 3 presents one of the UML diagrams from the "OP-NET" model. This diagram presents relations between geometric primitives inside "OP-NET" model. Our experiences from technical studies and technology demonstration performed during ALTBMD "Alliance Shield" consortium presented us that describing of object movement in 3D is more demanding than describing of flying aircraft. Special attention needs to be paid to presentation of velocity components. During analysis of literature [7],[8],[9] we found that ECEF (Earth centred Earth fixed) coordinate system used by rocket designers should be a good way to describe position of missile or satellite during surveillance and engagement process. Another extension of target motion description is a possibility of association of variance matrices for position, velocity and acceleration.

Representation of geometric primitives presented on figure 3 has of course the application in providing data to humans but also to the system services providing more advanced aids than data presentation. As an example we can mention TEWA module from SAMOC which takes data about ACO, air picture and weapon capabilities (list of required data is not full) and provides the list of threat tracks to the operator and other system elements.

4.0 USING ”TACTICAL ENTITY” DATA MODEL IN EXPERIMENTS

Later on we would like to present experiments conducted in the **S**ervice **O**riented **A**rchitecture world using transport technologies such as **D**ata **D**istribution **S**ervice. Subset of ”TacticalEntity” model was adopted to the required scope of information share and implemented.

4.1 Short introduction into DDS as a flexible and efficient middle-ware layer

DDS is a technology that emerged from the need of building distributed real time systems. The interaction architecture is based on publish – subscribe communication style, but the main advantage of DDS is QoS mechanism which allows for precise and flexible performance configuration and states the contract between subscriber and publisher, see [10]. Appropriate configuration of QoS helps in finding balance between reliability, performance, resource control, modularity and scalability. DDS is a solution especially for dynamic, distributed and heterogeneous real time environments and covers systems of different time constraints, from soft to hard real time requirements. The other important feature of DDS is that combining it with the Model Driven Engineering (MDE) approach allows for easy integration with RDBMS and other enterprise related technologies such as Web Services.

5.0 TACTICAL SYSTEM DOMAIN IN THE VIEW OF NNEC

NATO Network Enabled Capability (NNEC) enhances the efficiency and effectiveness of the Alliance by improving collaboration in an open and dynamic information environment. NNEC is based on the federation of various components of the operational environment in both the horizontal and vertical dimension. The integration has to spread from the strategic/upper level of command down to the tactical level, weapons and sensors. The issue is that the tactical level represents completely different characteristics and different technology domain. At this level reliability and real time constraints play the crucial role. The next important aspect of NNEC are joint force operations where the real challenge is to exchange information between C2 systems in air domain and land/maritime domain which are characterized by completely different dynamics. From technical point of view, the architecture paradigm which is accepted for NNEC is SOA (Service Oriented Architecture) and Web Services, the most commonly used technology for implementation of the SOA principle, have been identified as a key enabling technology for the NNEC information infrastructure. Web Services, due to their constraints finds really limited application in the implementation of tactical systems.

6.0 ENTERPRISE AND REAL TIME DOMAIN INTEGRATION CONCEPT

The main idea of the concept is the combination of two architecture paradigms SOA and EDA (Event Driven Architecture) which figure presents 4. Just as in NNEC, the general approach is based on enterprise context and SOA paradigm. In the case of real time processing the primary approach is EDA. The core of the architecture is RT Service Bus which plays the role of the service broker. The semantic interoperability is ensured by MDE approach which is generally based on the transformation of PIM (Platform Independent Mode) into proper PSMs (Platform Specific Model). This approach assures that the applications speak the same language across different domains.

All enterprise and tactical domain services can offer their capabilities using Service Discovery. The Semantic Service Description contains such meta-data as:

- name of the service,

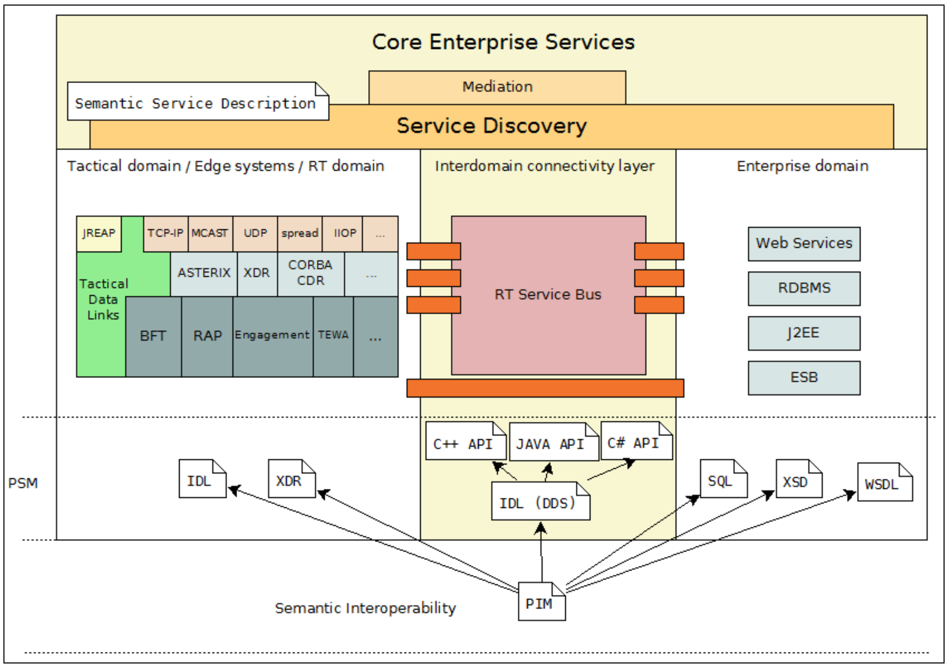

Figure 4: Multi-domain integration concept

- type of information,
- offered QoS,
- endpoint specification (the Internet address, file descriptor),
- protocol specification (type, version, etc.).

The role of Mediation Service is to compose service/data flows based on the offered and required capabilities and running scenario/business process. The architecture allows for flexible integration of enterprise applications using proper adapters to interface with real time domain. In tactical domain, applications can be provided with the best data exchange option according to the scenario, physical deployment, infrastructure constrains, etc.

7.0 GOAL AND COURSE OF THE EXPERIMENT

The aim of the experiment was to verify the concept described in section 6.0 in the context of joint forces integration of Land Forces and Air Forces based on MDE approach in SOA environment.

The main technologies and tools used for the demonstrations are: DDS as the base for RT Service Bus and UDDI for the semantic service description registry. The common data model is *Tactical Entity* mentioned in previous chapters.

Two following adapters were developed:

- SZAFRAN/NFFI to DDS Tactical Entity, as reliable service (Windows, C#, Java)
- DUNAJ/ASTERIX (001, 147) to DDS Tactical Entity, as best effort service (Linux, C++, Java).

The idea of demonstrator for ASTERIX (and NFFI on the same basis) is depicted on figure 5. The ”DDSDomainMonitor” collects dynamically notifications about service providers (”RAPServiceAdapter”) and register them accordingly in UDDI with all necessary meta-data. The enterprise application needs

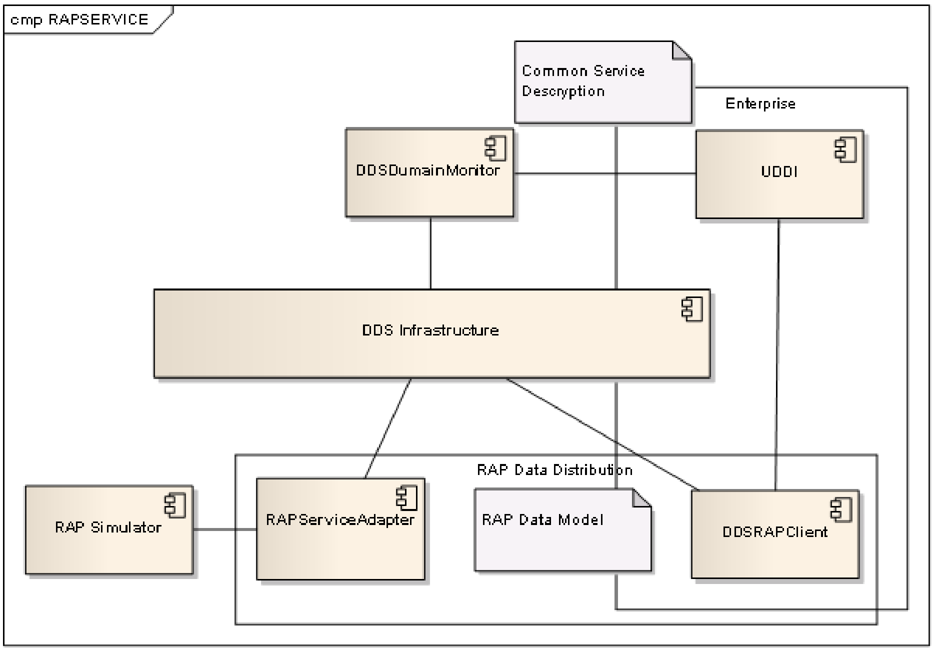

Figure 5: ASTERIX/RAP distribution service in multi-domain environment

proper plug-in (”DDSRapClient”) to consume data. In the demonstrator the RAP picture is transformed into NVG (NATO Vector Graphics) format and presented in the BRITE environment used as COP (Common Operation Picture). The result is visible on the BRITE display which is presented on the figure 6.

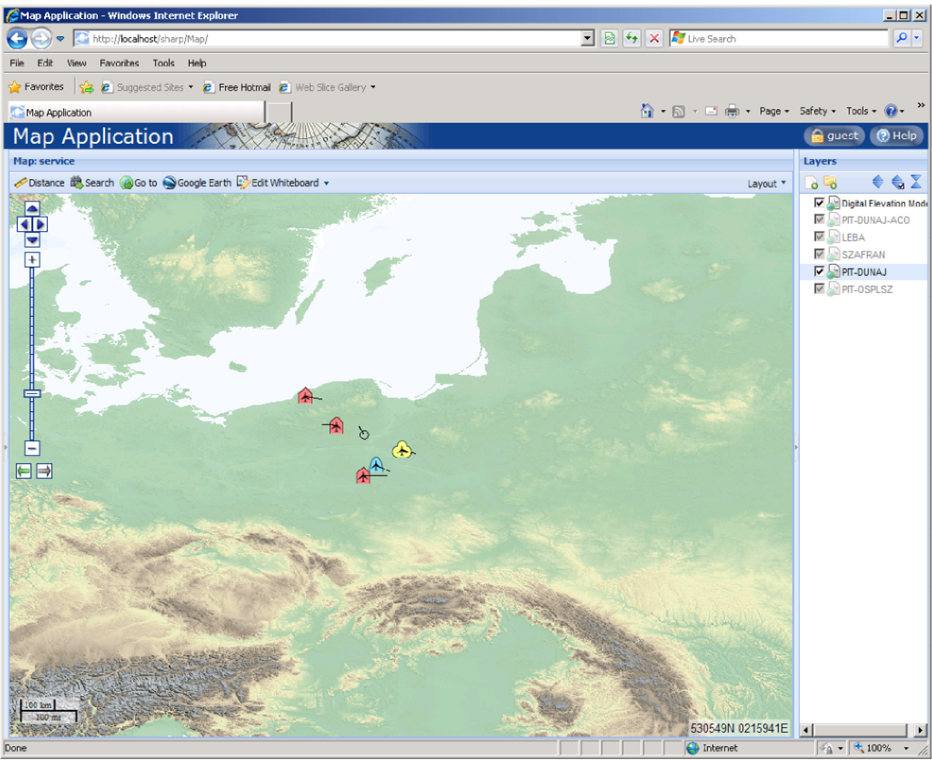

Figure 6: RAP visualisation in BRITE

Figure 7 shows physical deployment of the components. OSPL is a DDS implementation infrastructure that has been chosen for the demonstration. It is worth to mention here that the environment is based on Windows and Linux platforms and many programming languages listed earlier in this section. It proves heterogeneity of the solution in the aspect of technology.

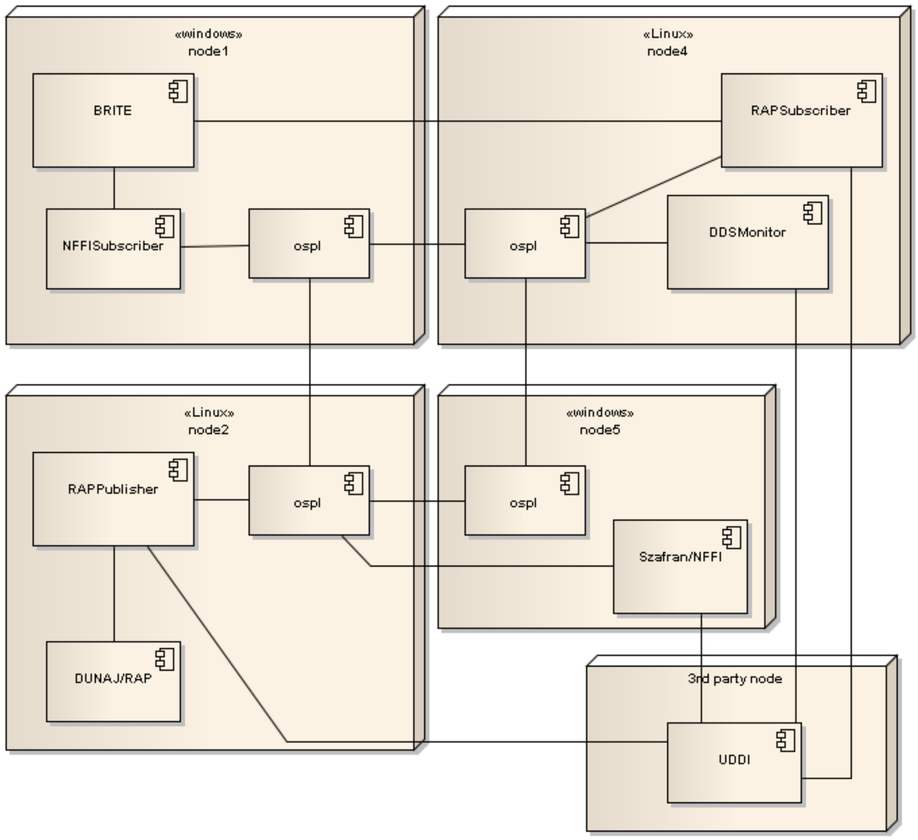

Figure 7: Test environment deployment diagram

The development process contained the following steps of model transformation:

- Transformation of Tactical Entity PIM to PSM (DDS IDL), selection of Topic Key (corresponding to DBMS primary key)
- Transformation of DDS IDL to Java/C++/C# stub classes (DDS automated tools)
- Semantic mapping, syntactic mapping (implementation of business logic)

During development stage the most problematic issues were mapping and optimization of PIM to DDS capabilities and topic key selection and assignment. The real challenge for future development is automated process of transformation between XML and non-XML data formats. The key technology which was selected for the demonstrator turned out to be promising for future integration activities. The experiments confirmed many advantages and flexibility of DDS but the relevant issue about this technology is that it is new and still needs a lot of experimentation and testing.

8.0 CONCLUSIONS

In this article we presented evolution of object-oriented models used for gathering knowledge about tactical situation. Both ”OP-NET” and ”TacticalEntity” were used in C2 Real-Time domain. Development of

”OP-NET” integrating elements such as: radar systems, CRCs, SAMOCs, airfields showed that modelling information domains is very needful in order to assure proper information transfer without human errors.

Working on multi-domain integration concept and demonstrator allowed us to participate in semantic network experiments learning how to exchange information between systems from various domains which is especially important in the view of future integration with higher level of command and NNEC. The proposed concept widens spectrum of applications in the future military system integration.

The other important conclusion resulted mainly from many years of experience in tactical system engineering and presented experiments is the issue of valid system architecture. Building the latter is a complex process, system architects should have huge expertise in wide range of technologies, especially in the domain that system is built for. Proper design decisions at the stage of building architecture are crucial not only for project success but also for the whole product life cycle. Wrong assumptions can lead to the situation where even after successful implementation of the full requested functionality, the usability of the system is not satisfactory due to poor performance or frequent failures. The other important thing is possible future system integration or extension as well as maintenance costs. The area of special importance is mission critical systems domain, where the main determinants are safety and human life, the consequences of wrong architecture can have tragic consequences.

REFERENCES

[1] Amanowicz, M., editor, *Zaawansowane metody i techniki tworzenia swiadomości sytuacyjnej w działaniach sieciocentrycznych*, No. ISBN: 978-83-61949-16-9, PTM, 2010.

[2] Walczak, A. and Szpakowicz, R., “Problemy badania świadomości sytuacyjnej operatorów przy budowie zobrazowania COP,” *Metody wytwarzania i zastosowania systemów czasu rzeczywistego*, edited by L. Trybus and S. Samolej, No. ISBN: 978-83-206-1780-1, WKiŁ, Warszawa, 2010, pp. 127–137.

[3] Eriksson, H.-E. et al., *UML 2 Toolkit*, No. ISBN: 0-471-46361-2, Wiley Publishing, Inc, 2004.

[4] “Rational Rose, Using Rose CORBA,” Electronic Documentation, March 2000.

[5] Yair Amir, Claudiu Danilov, J. S., “A Low Latency, Loss Tolerant Architecture and Protocol for Wide Area Group Communication,” Tech. rep., Department of Computer Science, Johns Hopkins University, 2000.

[6] “RFC 4506, XDR: External Data Representation Standard.” .

[7] Clynch, J. R., “Earth Coordinates,” Electronic Documentation, February 2006.

[8] Baleri, G., “Datum Transformations of NAV420 Reference Frames,” Electronic Documentation, October 2004.

[9] http://www.ublox.ch, “Datum Transformations of GPS Positions,” Electronic Documentation, July 1999.

[10] Object Management Group, *Data Distribution Service for Real-time Systems Specification*, version 1.2, formal/2007-01-01 ed., January 2007.