An Overview of the Research and Experimentation of IST-090: SOA over Disadvantaged Grids

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**Abstract:** Service Oriented Architecture (SOA) provides agile C2 functionality as services on a network, delivering flexibility, scalability and redundancy. SOA is currently available at the higher levels of command such as (deployed) headquarters, but not at tactical levels. We believe that a SOA approach at the tactical C2 level facilitates a next step in the evolution of C2.

SOA is a proposed paradigm for delivering C2 at the tactical level. The objective of Task Group IST-090 of the NATO Research and Technology Organization’s Information Systems Technology panel is to identify improvements for making SOA applicable at the tactical level, which typically include communication grids that are disadvantaged by line-of-sight connections, low bandwidth, intermittent availability, etceteras. IST-090 investigates how SOA can be used over disadvantaged grids and builds demonstrations that show how the challenges that are posed by disadvantaged grids can be mitigated. This paper describes the approach used by IST-090, including the following topic studies:

- Web-Services implementation: identify key elements for performance improvement, identify Web-Services limits;
- Service Discovery: performance, candidate technologies, experiments;
- Data Distribution Service: performance tests, connecting to Web Services;

This paper provides a link to some IST-related papers at the MCC that have been submitted by the IST-090 member nations. Together, these papers form a next step in the promulgation of the work of IST-090. This paper also provides preliminary information on demonstrations that IST-090 will provide at the IST-090 closing event, in conjunction with MCC.

1. **Introduction of Task Group 090**

IST-090 is one of the Task Groups of the NATO Research and Technology Organization’s Information Systems Technology panel [9]. IST-090 consists of the following member nations / organizations:

- Denmark (DNK)
- France (FRA)
- Germany (DEU)
- Great-Britain (GBR)
- Italy (ITA)
- NATO C3 Agency (NC3A)
- Norway (NOR)
- Poland (POL)
- Spain (ESP)
- The Netherlands (NLD)
- Turkey (TUR)

The first main message of this paper is to convey the challenges that are posed by the disadvantaged grids, that are deployed on the battlefield, to the implementation of SOAs. The disadvantages of these grids (networks) must be considered relative to the reliable high-speed grids that are commonly used for implementation of SOAs, within NATO as well as within the civil world.

The second main message of this paper is to discuss the objectives of IST-090 and the work done by IST-090. IST-090 runs from January 2009 to December 2011 and has the following objectives:

- Identify improvements to make SOA applicable on battlefield disadvantaged grids.
- Investigate Communication Paradigms, Mechanisms to reduce needed bandwidth, Mechanisms to improve reliability (deal with intermittent connectivity, link instability and latency).
- Results should not impose interoperability restrictions. We should limit changes to client applications as much as possible to take the full advantage of the most visible benefit of web services: providing interoperability in a heterogeneous environment.
- Promulgate the findings of IST-090. This will be done in a report to be published for NATO-RTO and also by providing papers and demonstrations (as for instance in cooperation with the MCC).

The paper links to several other papers that are provided by the IST-090 team members. Each of these papers offers an overview of research and/or experimentation related to the identification of improvements for making SOA applicable at the tactical level.

IST-090 is doing experiments and builds demonstrations that show how the challenges that are posed by disadvantaged grids can be mitigated. Some of these demonstrations will be shown at the MCC. These are described in this paper (at a high level).

2. Introduction of SOA at the tactical level

Service Oriented Architecture (SOA) is a design paradigm that can be used to make C2 functionality available as software services over a network. Examples
of such C2 functionalities are chat, speech (Voice over IP), observation report, real-time status, common operational picture, weapon availability, fire support request, Blue-Force Tracking, etceteras. Such SOA enabled C2 Services can be made available in a flexible, scalable and redundant way. For the end user there will not be much difference with current implementations of C2 functionality, except for the fact that there will be access to more and more specific information that will be more readily available.

SOA bases itself of the concept of wrapping software capabilities as services. In this context, a service is a piece of software that offers some sort of capability/functionality to others using standardized interfaces. This allows for the loose coupling of user and service that is essential if one is to deploy this technology in tactical networks.

The perceived value of SOA is that it provides a powerful framework for matching needs and capabilities and for combining capabilities to address those needs [11]. By OASIS\(^1\) definition [10], SOA is “a paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains. It provides a uniform means to offer, discover, interact with and use capabilities to produce desired effects consistent with measurable preconditions and expectations”. It is natural in such a context to think of one person’s needs being met by capabilities offered by someone else or, in the world of distributed computing, one computer agent’s requirements being met by a computer agent belonging to a different owner.

The use of SOAs has emerged as a major trend within the commercial sector and among nations developing NNEC type capabilities, because of the flexibility they provide in sharing information and information processing capabilities. SOAs provide mechanisms for using existing information services as well as providing a basis for developing new more advanced information services. Such mechanisms will allow many C2 needs to be satisfied by linking together existing information services in a modular, flexible fashion that can be readily adapted to changing operational context. The flexibility provided through the use of SOAs is particularly well suited to supporting the needs of coalition based Network-Centric Operations using systems of various nations, on different levels of transformation without the need of replacing them but only integrating into the SOA environment.

The value of SOA is that it provides a simple scalable paradigm for organizing large systems that require interoperability to realize the value inherent in the individual components. Indeed, SOA is scalable because it makes the fewest possible assumptions and also minimizes any trust assumptions that are often implicitly made in smaller scale systems. Moreover, apart from its inherent ability to scale and evolve, the infrastructure SOA encourages is also more agile and responsive than the one built on an exponential number of pair-wise interfaces. Therefore,

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\(^1\) OASIS – Organization for the Advancement of Structured Information Standards
SOA can also provide a solid foundation for developing operational context, based on business agility and adaptability.

As mentioned above, the flexibility and loose coupling offered by the SOA paradigm means that both NATO and many of the NATO nations are basing their future information infrastructures on this paradigm. Web services, the most common and mature technology for implementing SOAs, will inevitably be a part of this development, at least for use in fixed infrastructure networks.

As Web services are developed for use in civilian networks, they will not necessarily perform satisfactorily in radio-based military networks. It is however vital that solutions used in tactical networks are able to fully interoperate with SOA solutions on other levels and there exists two possible approaches to achieve this:

First, one can use Web services on the tactical level and make improvements to both the Web services themselves and to underlying infrastructure to ensure that the Web services become less bandwidth intensive. The benefits to this approach include:

- All services and clients, no matter where or how they are connected to the infrastructure, interact with each other using the same interfaces (so the same services can be used everywhere without modification).
- Cross network interoperability is easy, since the same technology is being used at the application level everywhere.
- Using the same solutions everywhere means fewer solutions that need to be maintained and monitored.

Secondly, we can use non-Web service technology on the tactical level and provide interoperability through the use of gateways. The benefits to this approach include:

- As nothing is given up front, a non-Web service solution can be designed more specifically for the limitations of each individual network and can potentially be optimized further than Web services?
- Other solutions can provide functionality beyond what is supported by Web services, such as more fine-grained QoS-support and support for real time data (this functionality will be limited to work within the network the given solution is deployed in though).
- Gateways will handle interoperability (developing these can generate significant overhead – one is needed per solution that is in use).

IST-090 investigates both these approaches, by both looking at how Web services can be optimized for tactical networks, while at the same time looking at other technologies that can be used to build a SOA at the tactical level. More specifically we are investigating the use of DDS as a SOA enabler on the tactical level.

The work is too much to tackle all at once by all involved nations together. Therefore we defined working groups: Adaptation of Web services for use in tactical networks and Service Discovery; DDS as an alternative for implementing SOA in tactical communications networks.
3. SOA-based C2 functionalities and NATO SOA concepts

Many SOA-based C2 functionalities are already available or being prototyped. The whole NATO concept is being developed based on the SOA concept (Core G, FFT, NMMR, IEG, NIRIS, MCCIS, BRITE – BWS). Many other countries have also shown their SOA – based implementations (Germany – SPC SOA, France – FoCCs-SOA, Finland – Mevat) [1]. Utilization of SOA-based implementation of Web Services in a NEC environment has been shown in many international experiments. These prove that SOA technology improves collaboration, interopera-
tion and information sharing in a Federation of Systems (FoS) [6].

Together, the nations that participate in IST-090 have much relevant expe-
rience in the area of implementing SOA in the area of C2. Some examples are
provided below:

Example: Coalition Warrior Interoperability Demonstration (CWID)

The CWID demonstration [1] evaluates technologies and capabilities for
exchanging information among coalition partners, military services, govern-
ment agencies, first responders and U.S. combatant commanders. Information
sharing technologies leverage decision-making and operational flexibility on the
battlefield and during crisis response on the home front. Two specific CWID
examples are described:

CWID 2006

SOA solutions need to work with different types of information and com-
munication systems. During CWID exercises in 2006 tests of SOAP web services
were performed that resulted in the conclusion that "service-oriented architecture
implemented via the technology of Web services is the strategic means to achieving
interoperability". However particular problems related to the utilization of protocols
of the SOA stack like TCP/HTTP/SOAP have been recognized [16].

CWID 2007

Another example of SOA-enabling of C2 software is an experiment [3] that
took place at NATO CWID 2007, in which a hand held soldier system was connected
to an already existing national C2 system using a Web service interface.

Example: BRITE

The Baseline for Rapid Iterative Transformational Experimentation (BRITE) is an experimenta-
tion framework which allows for the rapid implementation of new ideas and capabilities to support experimenta-
tion. It fits into the TIDE (Transforming Technology for Information, Decision and Execution superiority)
concept. Its goal is to rapidly improve the IT capabilities of the NATO Alliance by
reusing existing systems/components and by steering current and future projects
towards greater openness and cooperation in a common framework. WISE 2.0 is
part of this BRITE framework. These components are implemented as a Service
Oriented Architecture (SOA).
**Example: Multi National Experimentation 6 (MNE 6) in phase 4.2**

This experiment is used to test technical possibilities in sharing maritime situational awareness between systems of the Baltic Sea. It encompasses Multi-national Inter-agency Situational Awareness – Extended Maritime (MISA–EM). It includes e.g. the following systems: FIN: Mevat; SWE: Suchbas; POL: SWIBZ, NATO: BRITE, all based on web services and SOA based solutions [15].

**Example: Norwegian national experiment**

Figure 1 (from [8]) shows the many ways SOA services can be constructed, either as a new SOA service, as a wrapped legacy service or as a composite service. During a Norwegian national experiment [4] several of these mechanisms were tested using an experimental Cooperative ESM Operations (CESMO) software. This software was wrapped using Web service standards and was thus made available to new users. In addition, new functionality, in the form of an NFFI blue track service, was created from scratch using the same data sources.

![Diagram of different ways to construct SOA services](image)

**Example: Joint NC3A/NOR experiment at Combined Endeavor 2009**

At Combined Endeavor (CE) in the Netherlands, 2009, experiments were performed using Web services in mobile networks and over reach-back links back to deployed infrastructure (i.e., the HQ) [5]. Here, we were able to show the feasibility of employing Web services in an operational experiment for a specific set of communications hardware: NC3A used Rajant Breadcrumbs, whereas NOR used the KDA WM600 tactical radio. We were able to successfully discover and invoke Web services across the heterogeneous networks, through the use of proxies for delay tolerance and gateways for network- and discovery protocol interoperability.
4. Objectives of IST-090

This chapter explains the objectives of IST-090.

4.1. Area of research and scope

The overall research focuses on the use of SOA on disadvantaged grids (e.g. Mobile Ad-hoc Networks) in “near real time”. Sub-areas of research include:
- Communication paradigms
- Mechanisms to reduce needed bandwidth
- Mechanisms to improve reliability
- Security: Requirements posed by security will only be taken into account as far as relevant. Security is already the focus of other groups (IST-053, IST-061).

To evaluate our propositions for solutions we will use a concrete scenario as a global context of the study. The scenario will incorporate use cases and services (i.e. Blue Force Tracking, Observation report, Alert notification, UAV video feed, weather forecast...). An example of scenario is provided below.

![Scenario Diagram]

Figure 2. Example of Scenario

In figure 1 we have two kinds of SOA design and implementations: Regular (without Disadvantaged Grid limitations) and Adapted to tactical needs (with...
Disadvantaged Grid limitations). IST-090 will take in consideration the overall context of the scenario but will focus on SOA adapted to tactical needs.

To become a bit more concrete, we identify some examples of services that are applicable in this scenario. Common Operational Picture (COP), the Compilation, distribution and contribution of relevant information; Blue Force Tracking (BFT), providing information about own forces location; Intelligence Surveillance Recognition (ISR) Feed, the ability to access ISR Sensor information; Call For Fire (CFF), Fire support requests containing all information needed to determine the method of target attack. For the scenario the CFF comes from an observer; Alert Service, this is a high priority instant advertising of incoming emergencies and contingences; Observation Report, this involves the distribution of information collected on the battlefield through observation by deployed soldiers and a variety of electronic sensors; Database Search, this can consist of remote requests of information relevant to the operation by deployed units; Online Status, this involves monitoring the availability status of deployed units; Notification, this is the ability to be notified when a subscribed data changed. It is linked to a data subscription approach; Others: Chat, VoIP, Video, etc.

4.2. The specific goals and topics to be covered by IST-090

In the scenario described in the figure 1 it is possible to discern the following issues that should be analyzed to find the solution for making SOA applicable to Disadvantaged Grids.

Areas of research that are proposed to investigate include (but are not limited to):

- Communication paradigms: Request/Response, Publish/Subscribe (Message-centric approach, Data-centric approach). Technologies that support Publish/Subscribe pattern are: CORBA Notification Service; Web Service Notification; Message Oriented Middleware (JMS) and Data Distribution;
- Reduced dynamic service discovery;
- Mechanisms to reduce needed bandwidth (e.g. compression);
- Mechanisms to improve reliability (deal with intermittent connectivity / link instability and high latency);
- Adaptation of web services based on the context of the service call.

5. Overview of the IST-090 related papers at MCC

This chapter provides links to other IST-related papers at the MCC, submitted by the IST-090 member nations. This concerns the following papers (placed in alphabetical order of titles):
5.1. DDS technology demonstrations related to IST-090

A Technology Demonstration was set up to demonstrate the capability of DDS middleware (Data Distribution Service) as integrator of different systems in the context of a military operations. The core of the demonstration was a set of DDS services designed by the Spanish Army. These DDS services (Unit Information, Tactical Messaging, File Distribution and Video Distribution) are currently being implemented in real systems and several Spanish companies were invited to participate in developing and testing in a joint environment to recreate a tactical scenario using those services in its existing systems. Along with the DDS services, another technology such as SOA was implemented and a gateway between both services DDS and SOA was implemented. This gateway was able to transform information from the Unit Information Service (DDS data model) to the COP’s (Common Operationl Picture) web service [2].

5.2 Independent evaluation of a number of published approaches that purport to improve the reach of web services into locations with disadvantaged networks

In this paper we report on a project that has independently evaluated a number of published approaches that purport to improve the reach of web services into locations with disadvantaged networks. The original analyses produced were incompatible and thus of limited value. This project has brought them into a directly comparable framework. We also analyse raw web service and other very low cost solutions to provide a context in which to view the results of the published solutions. The output of the work is advice on how and where to use each of the solutions in order to facilitate the delivery of web service based SOA systems over disadvantaged networks [18].

5.3. Mediation of network load over disadvantaged grids using Enterprise Service Bus (ESB) technology

One of the main aspects of a (SOA), and thus the future NNEC, is that of the dynamic discovery and utilization of services. However, it is likely that different versions of a service will be offered, physically located within separate parts of the enterprise infrastructure. If the SOA infrastructure could be designed to be “network aware” then the user could be automatically directed to the proper instance of a service based upon the status of the end-to-end connection between the user and service, and the required quality of service. A network-aware SOA would need to facilitate the adaptation of a service depending on the status of the connection between the client and the server or between two end users (depending on the scenario). With the goal to provide a ubiquitous, global, seamless, pervasive,
fully managed, resilient, secure and flexible Internet Protocol (IP) based communications capability including wired, wireless and SATCOM bearer services, the services in a service-oriented architecture need to have the ability to adapt to the current network conditions. This especially applies for disadvantaged users, such as in a MANET (mobile ad-hoc networking) extension of a fixed network. Depending on the available data rates, error rates, delays etc. different variants of services can be supported [7].

5.4. Review of service advertisement and service discovery (SASD) algorithms

SOA is an approach to designing information systems that promotes good management and cost effectiveness through reuse and easy reconfiguration. The concept being that through a thorough understanding of service level agreements, service descriptions and finding new service providers you are able to allow competition between IT suppliers to drive down costs and drive up value. However, although many of the technologies exist to support these goals, and they are even embedded within most of the SOA implementations offered by the major vendors, they are rarely used in commercial projects. Instead, commercial IS system developers prefer to pre-configure the SOA interconnections. We believe that this gives them greater confidence in the stability of their system.

One major issue is that the system houses do not trust the service advertisement and service discovery (SASD) algorithms to correctly find the “correct” provider at any given time. One issue they face is that although there are many SASD algorithms they have not been evaluated in a common framework that allows direct comparison of the results. This paper reports on a review that looked at SASD algorithms and other reviews of them. It identified several that we considered to demonstrate very different approaches to the problem. Each was then implemented within a common evaluation framework and through direct comparison, conclusions were drawn concerning their effectiveness [12].

5.5 Semantic description of QoS framework for context-aware web service provision

The paper presents semantic description of web service QoS profiles that is part of the larger framework for context – aware service provision. It consists of upper-level ontology that defines basic concepts and their relationships generally known from ITU-T recommendations and domain ontology for web service provision that specifies user QoS profile, service QoS profile and network performance. This Quality of Web Services (QoWS) model can be used for (1) service discovery enabling to match user QoS requirements and service QoS offerings, and (2) service delivery, including adaptation actions in order to support QoS provision for web services
in disadvantaged wireless environment. The model is based on existing ITU-T QoS descriptions and Web Service QoS models defined e.g. by OASIS and W3C [13].

5.6. Towards a middleware for tactical military networks – interim solutions for improving communication for legacy systems

A crucial aspect in constructing an information grid will be the full integration of the tactical level. Mobile units deployed on the tactical level are connected by disadvantaged grids. Optimized utilization of the communications resources is essential. To fill the gap between C2IS build for high-speed LANs and tactical networks based on narrow-band radio links, a middleware for military heterogeneous networks is needed, which mediates between C2IS and the underlying military network technologies [14].

5.7. WS-DDS interface (gateway) for tactical network

The paper presents results of the study on the exchange of data between Web Services (WS) and Data Distribution Service (DDS) using WS-DDS Interface. WS-DDS Interface connects two architecturally different message exchange solutions dedicated for two different environments. Web Service is system-independent application very often used in over-provisioned network. DDS is designed for real time applications. It works in publish–subscribe mode providing efficient solution for resource constrained networks. The WS-DDS Interface presented in this article enables bi-directional traffic between WS and DDS, with regard to the timeframe of the protocol and data transformation, which is a very important factor in success of a mission [17].

6. Overview of the IST-090 related demonstrations at MCC

IST-090 strives to present several demonstrations at MCC 2011. Note that the information about the demonstrations in this paper does not provide a high level of detail and is partly tentative. This is because the demonstrations are still being worked on at the time of writing of this article.

6.1. Making services interoperable

NC3A, Norway, and Poland and will provide a demonstration that combines different approaches to overcome the challenges posed by disadvantaged grids.

The demonstration will show that, regardless of the different technologies used, services can be made interoperable. A Data Distribution Service (DDS) domain will be distributed through a gateway to a Web Service environment where the DSpProxy or a Enterprise Service Bus (ESB) optimises the use of bandwidth and manages limited connectivity.
The constrained network conditions will be provided through either a Mobile Ad Hoc Network (MANET) or different network simulators.

6.2. MIST

MIST is an experimental protocol for publish/subscribe in MANETs. It leverages node mobility and application layer epidemic routing to achieve information dissemination without relying on a functioning routing layer or IP multicast support. MIST is resource efficient, and designed to overcome the limitations of networks with scarce resources. It can be used for any publish/subscribe application, and has earlier shown promise when applied as a service discovery protocol for Web services. Especially in tactical scenarios communication bandwidth is scarce. A better coordination of C2IS applications with the different network technologies can improve the overall user experience.

6.3. Middleware for tactical military networks

The Fraunhofer FKIE demonstrates an interim solution for a middleware that is able to mediate between C2IS applications and network protocol layers in heterogeneous network environments, including low speed tactical communication links. The interim solution consists of a software upgrade that can be deployed in the operational system as an additional software component without modification of the original C2IS.

7. Conclusions

- IST-090 has brought together the knowledge and experience of the member nations;
- A technology demonstration, with the focus on DDS, was organized and held successfully in Madrid 2010;
- A part of the research was captured and provided as papers in the MCC 2011;
- Several demonstrations will be provided at MCC 2011;
- A final report will be provided for NATO-RTO.

REFERENCES


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