Paper

Sharing tactical data in a network-enabled coalition

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Abstract—The NATO Command, Control and Consultation Agency (NC3A) is a participant in a coalition project called the Shared Tactical Pictures (STP). The aim of STP is to develop methods and techniques to enable the sharing of a wide variety of information – e.g., ground surveillance sensors, airborne sensor platforms, recognized pictures, and much more – across a widely distributed network. As NATO changes its war-fighting paradigm from a well-known and stable alliance configuration to more flexible, coalition-based operations, solving the problem of information-sharing has never been more important. This paper discusses the technical and operational developments being explored in STP.

Keywords— ***service oriented architecture, Web services, coalition, concept of operations, shared picture.***

1. Introduction

As NATO changes its war-fighting paradigm from a well-known and stable alliance configuration to more flexible, coalition-based operations, solving the problem of information-sharing has never been more important.

There is a need to take an overall architectural view in order to produce an operational doctrine for coalition operations. This will facilitate developing some common rules in the deployment of command and control (C2) systems. This doctrine will be critical in guiding the IT part of coalition deployments in the future.

At the technical level, there is a need to ensure that authorized (but not unauthorized) users are able get the data they need – where they need it, when they need it. This information must be available regardless of where it actually resides and regardless of who "owns" it.

At the tactical level, the problem becomes even more acute, as one must carefully consider the network situation: the possibility of disadvantaged (slow, low bandwidth) links, communication failures and other problems that may affect the availability and reliability of this information.

Attempting to address these issues, the NATO Command, Control and Consultation Agency (NC3A) is a participant in a coalition project called the Shared Tactical Pictures (STP). The aim of STP is to develop methods and techniques to enable the sharing of a wide variety of information – e.g., ground surveillance sensors, airborne sensor platforms, recognized pictures, and much more – across a widely distributed network. And because it is being developed for a variable-profile coalition environment, the composition of the user group (data consumers) and the set of available information sources (data providers) are not necessarily known in advance and may change quickly over time. Thus it is critical that the environment be designed to be flexible enough to allow dynamic registration of data providers and the dynamic search for assets by data consumers. There is also a need to provide a smart data-fusion capability to merge information in a reasonable way and help the users make sense of all the information that is available.

2. Operational doctrine

With the advent and the formalization of new types of alliance missions and the complexity involved in the conduct of modern military operations, new challenges are outlined for NATO. Just to mention some of the central issues: considering the wide range of possible coalition scenarios[1], the "doctrine" adopted within the specific type of coalition is essential in the definition of the nature of command relationships, both between the assigned national/multinational forces and HQs and also between HQs. The policy and rules have to be defined on a case by case basis, since forces from partner and other non-NATO nations may be invited to participate and each of them have their own internal doctrines.

The implications of these rules closely affect the operational concepts and processes involved, not only as far as the deployment of C2 systems is concerned, but also the upstream process of collection and prioritization of commander's requirements, the subsequent assignment and control of (national) assets and the nature of orders to subordinates finally generated.

As a consequence, within NATO, a process of transformation and adaptation to the new emerging scenarios has been undertaken and significant effort is being put in the direction of systems interoperability achievement. To this purpose, an architectural approach to system design, through the implementation of agreed standards and products, is followed during the development of new C3 systems, which will then undergo a rigorous interoperability testing programme. This new approach is part of the so-called *NATO C3 System Interoperability Process* [1].

In line with the above, an *overarching NATO Interoperability Policy* [2] is under development. This policy must formalize processes in support of present and future execution of a full range of NATO missions and tasks and provide guidance for the harmonization of interoperability requirements. Among these is the need for single and joint

[1]Possible types can be: joint, allied multinational, lead nation coalition, and ad hoc coalition.

service capabilities – supplied by all participants – to cooperate and, in some cases, be coordinated to provide support for the achievement of a single goal.

Considering the huge amount of different facilities, in terms of network infrastructures, communication and information systems, in use by different nations, it can be reasonably assumed that this is a very challenging task, which requires a lot of work to set the premises and the environment in which the operational actions and missions will be conducted.

The Shared Tactical Pictures (STP) initiative – of which the first phase has been the shared tactical ground picture (STGP) – is attempting to solve the problem of information sharing in a coalition environment. In the words of the STP vision statement:

"In future coalition operations, all available information that may be relevant to the production of a decision-quality tactical ground picture, irrespective of source and type, is made available to all eligible participants to provide them with actionable information consistent with their military requirement and level of command."

STP is not the development of a new system, nor does it attempt to supplant existing national systems. Rather, STP is a process that defines short-term and low-cost tasks ("quick wins") in order to develop concepts, methods and standards that will extend utilization of existing information; share data in an interoperable environment; leverage national operational picture capabilities; and enable progressive development of interoperability of data, databases, applications, systems and networks.

In the context of the STP project, an activity of architecture modelling is under way, which at first stage is being characterized by the collection of information on the systems in use or under development by the nations, in terms of *policy, process* and *product*. This does not simply mean an inventory activity, but also the examination of the state of the art as far as national facilities/capabilities are concerned, which are supposed to be used in future in an interoperable environment.

As a matter of fact, there are some reasonable issues that concur to slow down the course of this activity. One is the releasability of sensitive information by nations, in a context in which other participating nations, possibly not known in advance, can access that information. As far as *policy* is concerned, this has a very high implication in assembling the concepts of the adopted national doctrines. On the other hand, the STP community has agreed that currently existing rules and policies should constitute the basis for establishing more general high-level rules, applicable in a dynamic coalition environment.

The reluctance by nations to release information also affects the clear understanding of "what" can be shared within the coalition, i.e., national owned assets and systems along with their capabilities and products. Addressing this issue is a key goal of the STP initiative.

Under the term *process*, all the envisaged CONOPS[2] and TTP[3] are to be considered. Focus points that need to be described in detail are relationships between different level of commands, information cycles/flows between different operational nodes and the coordination of the operational staff itself. All these are key points for the effective and prompt tasking of available systems and for the provision of as much appropriate and timely support as possible to satisfy the original requirements during a mission.

An overall knowledge of the associated components, *products* and services of the existing systems taken into account are also of great importance to see how much is covered so far. Some emphasis has been placed on four different types of system products: BA[4], C2-BFT[5], ISR[6] and NC[7]. An appropriate analysis should also lead to the detection of possible gaps in the wide range of system capabilities required by the users at all LOCs[8].

Even if a number of the mentioned issues are still at the investigatory phase and will probably get no satisfactory analysis results, the ongoing activity is intended to serve as vehicle for reaching a common understanding on what a general coalition doctrine might be in order to lay the basis for building up a real concept of interoperability amongst heterogeneous environments and finally enable the achievement of a common operating picture, in order to speed-up the decision process and the course of actions.

3. Service oriented architecture

Service oriented architecture (SOA) is an architectural style whose goal is to achieve loose coupling among interacting software agents. A service is a unit of work done by a service *provider* to achieve desired end results for a service *consumer*.

Consuming a service is usually "cheaper" and more effective than doing the work ourselves. This is called "separation of concerns", and it is regarded as a principle of software engineering.

SOA achieves loose coupling among interacting software agents – which can be systems, users or devices – by employing two architectural constraints:

- A small set of simple and ubiquitous interfaces to all participating software agents. Only generic semantics are encoded at the interfaces. The interfaces should be universally available for all providers and consumers.

[2]Concept of operations, they provide the vision for users on how systems/capabilities are operated and utilized.

[3]Tactics, techniques and procedures for the operation and exploitation of assets. They are usually aimed at for commanders, staff and operators directly involved in the planning and tasking of interoperating assets, at both the operational and tactical level.

[4]Battlespace awareness.

[5]Blue force tracking.

[6]Intelligence, surveillance and reconnaissance.

[7]Net-centricity – the idea behind it is the flexible integration of command posts and decision centres, sensors and sensor systems, warfighters and commanders in a netwsork, to enable an operation.

[8]Level of commands.

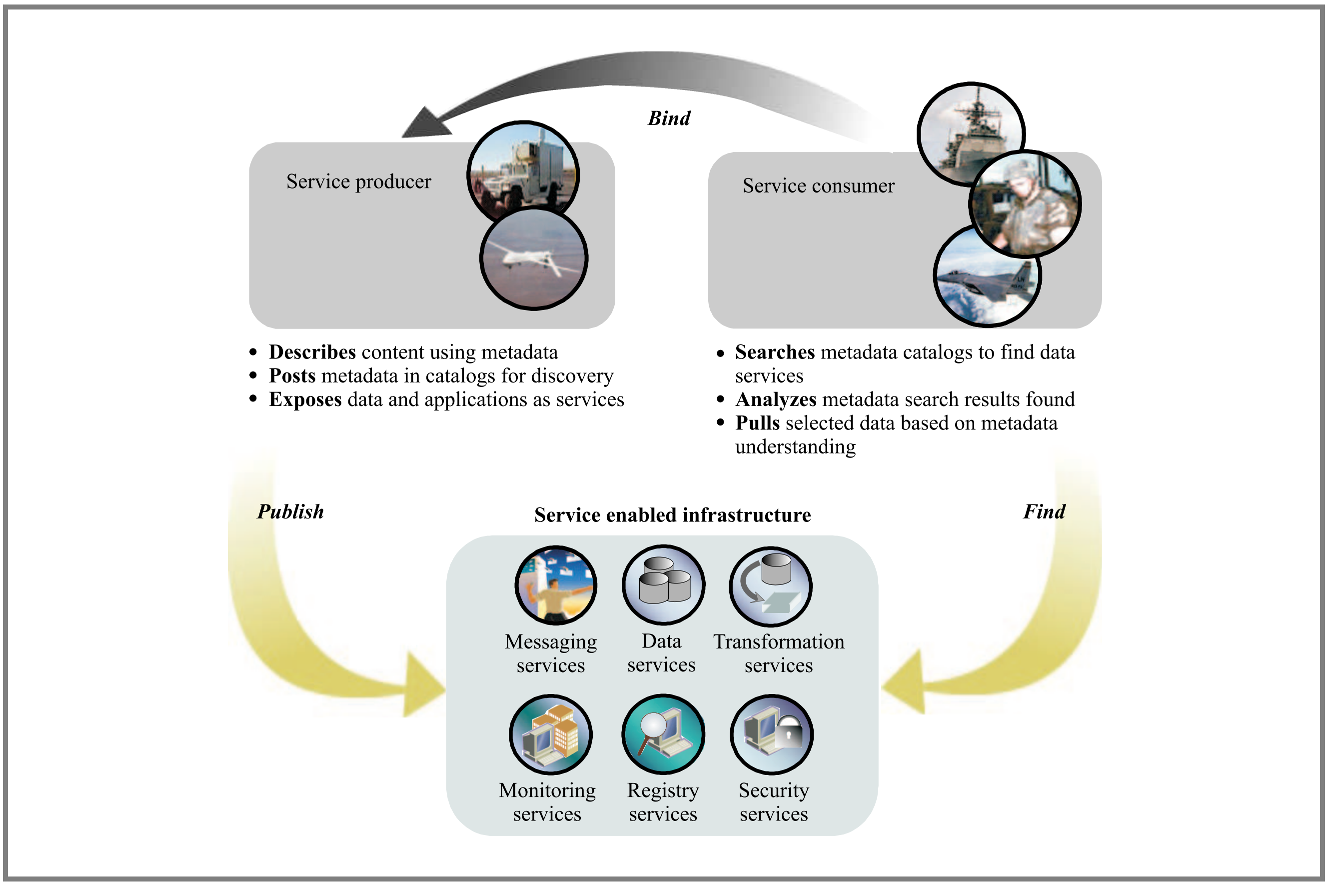

Fig. 1. Service oriented architecture (diagram courtesy of Booz Allen Hamilton [6]).

- Descriptive messages constrained by an extensible schema delivered through the interfaces. No, or only minimal, system behaviour is prescribed by messages. A schema limits the vocabulary and structure of messages. An extensible schema allows new versions of services to be introduced without breaking existing services. This schema is based on XML[9], the de facto standard language of inter-system communication.

3.1. SOA roles and operations

Any SOA contains three roles: service consumers, service providers, and a service registry (Fig. 1).

- A **service provider** is responsible for creating a service description, publishing that service description to one or more service registries, and receiving invocation messages from one or more service consumers.

- A **service consumer** is responsible for finding a service description published to one or more service registries and is responsible for using service descriptions to bind to or invoke service providers.

- A **service registry** is responsible for advertising service descriptions published to it by service providers and for allowing service consumers to search the collection of service descriptions contained within the service registry.

Each of these roles can be played by any program, software agent or network node. In some circumstances, a single software agent might fulfil multiple roles; for example, a program can be a service provider, providing a service to downstream consumers as well as a service consumer itself consuming services provided by others.

An SOA also includes three operations: *publish, find*, and *bind* (or *invoke*). These operations define the contracts between the SOA roles:

- The **publish** operation is an act of service registration or service advertisement. When a service provider publishes its service description to a service registry, it is advertising the details of service to a community of service consumers.

- The **find** operation is the logical dual of the publish operation. With the find operation, the service consumer states a search criterion, such as type of service, various other aspects of the service such as

[9]XML is the extensible markup language. An XML document is simply ASCII text that follows certain standard structural principles. XML is a "metamarkup" language. Unlike its cousin HTML – the language of Internet web pages – XML does not have a pre-defined set of tags and elements. Rather, an XML document is self-describing, allowing virtually unlimited types of content.

quality of service guarantees, and so on. The service registry matches the find criteria against its collection of published service descriptions. The result of the find operation is a list of service descriptions that match the find criteria.

- The **bind** operation embodies the relationship between the service consumer and the service provider. When the consumer attempts to invoke the publisher's service, a bind operation takes place.

The key to SOA is the service description. It is the service description that is published by the service provider to the service registry. It is the service description that is retrieved by the service consumer as a result of the find operation. It is a service description that tells the service consumer everything it needs to know in order to bind to or invoke the service provided by the service provider. (A popular analogy is the telephone book. A human customer uses the telephone book to learn how to access a business service, e.g., phone number, address; a service consumer uses a service registry to learn how to access an SOA service, e.g., location, invocation method). The service description also indicates what information (if any) is returned to the service consumer as a result of the service invocation [3, 5, 6].

4. The Shared Tactical Pictures

4.1. The STP concept

STP is all about sharing information in a coalition, without the need to develop expensive, time-consuming new systems.

A key element of STP is that it is a true multi-national project. Teams from the US, UK, Norway and NC3A have already been involved in the development process; other nations including Sweden and Italy are expected to begin contributing in 2005.

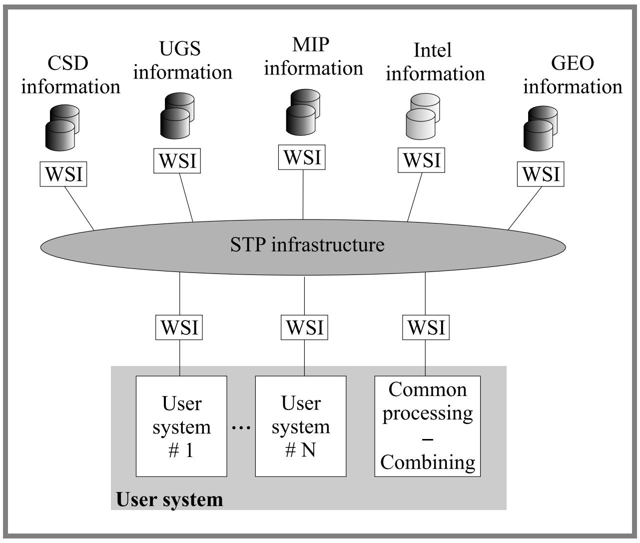

Fig. 2. The Shared Tactical Pictures.

The ultimate goal of STP is to create convergence amongst coalition interoperability initiatives. To do this, STP is developing an open, scalable architecture that will enable each nation to implement its unique solution while maintaining effective interoperability. This is illustrated in Fig. 2 with some representative data sources that will be described later in this paper.

This is where the service oriented architecture concept described above comes in. An SOA implementation, as described above, is perfectly suited for a highly heterogeneous, highly dynamic environment such as a variable-profile coalition. As a result, this is the design that has been chosen for the STP initiative.

The various data sources that have been integrated into the first phase, STGP (listed below), have exposed their core functionality as services. To do this, a set of Web service "wrappers" have been written as interfaces into the underlying systems. These services can then be accessed by any service-enabled client by issuing a standard SOAP[10] request, which results in data being returned in standard XML format. The existing systems have not themselves changed at all; rather, their functionality has been made available to the STP environment by means of these service interfaces.

The initial results have been promising. Data providers representing a wide variety of information have been integrated. These information sources share one common goal: each attempts to provide some kind of "picture" of ground activity in a certain area. The systems being used for STP include:

– unattended ground sensors (UGS);

– airborne surveillance and reconnaissance (SAR) systems that produce ground tracks (e.g., JSTARS, ASTOR, U-2);

– SAR systems that produce high-resolution images;

– existing systems developed to the multinational interoperability programme (MIP) standard.

These systems contain complementary data that are stored very differently; under normal circumstances would be quite difficult or even impossible for them to interoperate. To take one simple example, the airborne (SAR) sensors produce either ground moving track indicator (GMTI) or link-16 formatted data, while the SAR cameras generate images in binary format. Clearly, sharing this information in its native form presents a huge challenge.

[10]SOAP is the simple object access protocol. It is basically an "envelope" for an XML message in a SOA environment, containing routing and other header information for the message.

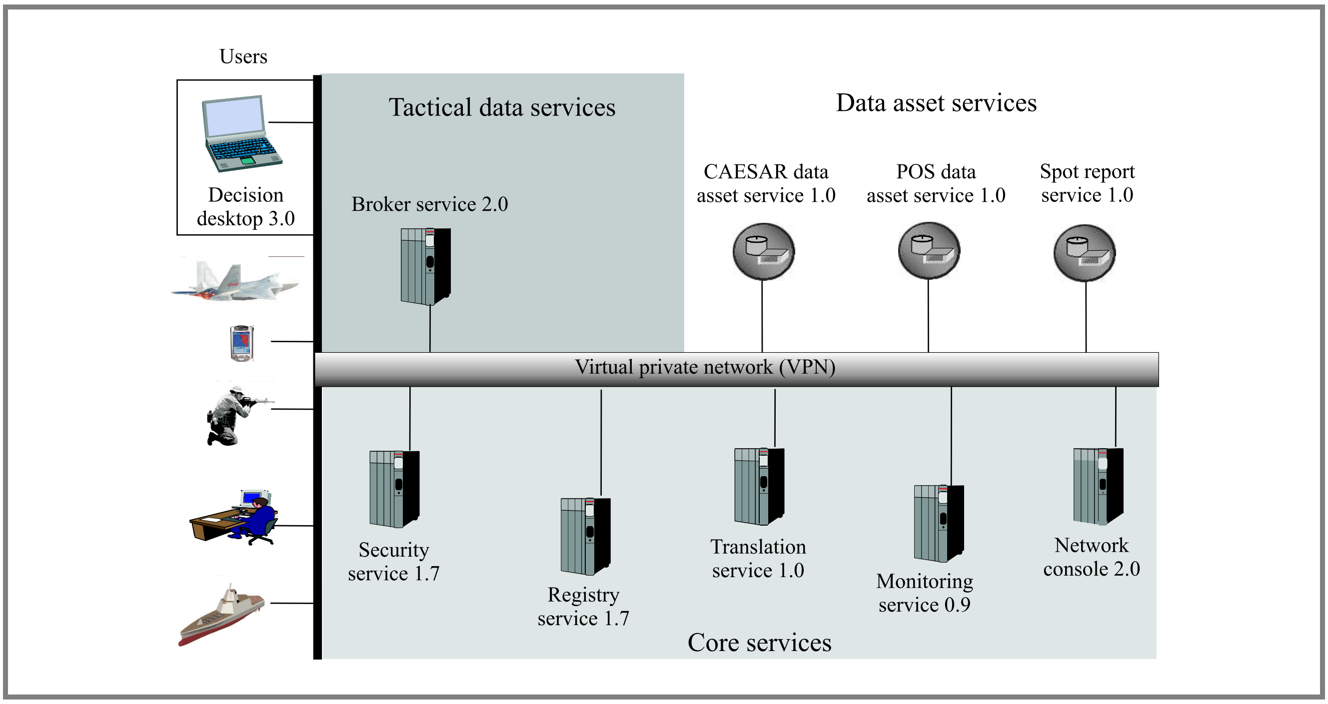

Fig. 3. The set of services developed for STP domain.

However, by developing a Web services[11] interface for each of these data sources – a "window" into their functionality – and by packaging the data as common XML, it becomes possible to share data among the disparate systems using an agreed-upon format, and it becomes possible for a user to make use of the different types of information offered by each of these platforms.

4.2. The STP Web services implementation

4.2.1. Producers and consumers

The set of services that have been developed for the STP domain is represented in Fig. 3. At the heart of the STP implementation are the so-called "Core services": services that represent some foundational functionality and which are available to all producers and consumers. The two main core services are the *registry* (based on UDDI) and *security*. (The registry, as described in the previous section, maintains knowledge of the location and access procedures for each service on the network. The security service, through the use of a public key infrastructure (PKI) issues and validates certificates to ensure secure transactions between consumer and provider.) In addition, there are a set of *translation* services and a *monitoring* service, which will be discussed later.

There is also a set of *data asset* services: providers of information to the coalition. In this case there are three primary service providers: the coalition aerial surveillance and reconnaissance (CAESAR) shared database (CSD), which aggregates ground track and imagery information coming from the various SAR platforms described above; the passive observation sensor (POS), which is the unattended ground sensor generating GMTI data; and spot reports, which give a human observer in the field the ability to enter text reports about what is being observed.

Finally, the *broker* service allows users to subscribe to data from certain sources. This will be described further later in this document.

The *consumer* for all this information can be almost anything, from a user with a web browser to a network-capable PDA to another system. For the purposes of the STP exercises, a visualization application called decision desktop (DD) has been developed, which has the ability to render all the different types of data (ground tracks, images, textual observations, etc.) being produced.

4.2.2. Dynamic data providers

When a service become available on the network – for example, when one of the airborne SAR platforms begins generating data – it communicates with the registry, providing the registry with three key items: *where it is located on the network, what services it provides*, and *how to access these services*. This is the **publish** operation described earlier, and it enables the other, data consuming services (such as the end user's system) to discover and make use of the service (the **find** operation described earlier). Finally, the consumer invokes the service (the **bind** operation) and receives the data.

[11]The term "Web services" refers to a specific instantiation of an SOA, one that is based on XML messages being transported via HTTP over TCP/IP networks. This is in fact the technology being employed by STP; therefore the terms "SOA" and "Web services" are often used interchangeably throughout this document.

4.2.3. Helper services

The SOA paradigm is largely a pull mechanism: the consumer (user) requests information from the producer and receives a response. The flaw in this approach is that it puts a burden on the consumer to keep up with the status of the producer; in other words, the only way the user will receive the latest information from a data source is if he continuously asks for it, and the only way the user will know if a new data source becomes available is if he looks for it.

This is where the *broker* service mentioned in the previous section comes into action. The broker acts on behalf of the user to check each data source for updated information; it also continually scans for new data sources of relevance to the user. For example, assume that a particular user is interested in all SAR imagery that is produced in a certain geographic area, regardless of the source, and wants it as soon as it is available. The user can set up a "subscription" with the broker service to continually poll the various data asset services and return up-to-date information as soon as it becomes available. The user thus no longer has to be concerned when services are dynamically added or removed, or when the data being offered by a producer changes, because the broker takes care of the interactions and automatically forwards relevant images to him.

A similarly valuable service is the *monitor*. In an SOA, the only way to know for sure if a registered service is indeed available is to issue a query to it; if the query fails then the service is unavailable. Clearly this is inefficient, especially if there are many users (or brokers on behalf of users) constantly doing this. Therefore, STP has developed a monitoring service that constantly evaluates the state of all services on the network. When a user (or broker on behalf of a user) wants to see which services are currently available, it merely issues a request to the monitor for the latest status.

Finally, the *translation* services give the capability to translate data from the format offered by the data provider into one preferred by the data consumer. For example, as discussed earlier the airborne SAR platforms (e.g., JSTARS) produce ground tracks in a tactical data link format called link-16. The web service that acts as the interface to these systems presents the data as an XML representation of link-16. However, the default data consumer in the STP environment (decision desktop) requires its information to be delivered in a common data specification known as resource description framework (RDF). Therefore, STP provides a link-16-to-RDF translator service, which is automatically invoked when the decision desktop consumer accesses the JSTARS provider. By the time the data reaches the consumer, it has been translated from an XML representation of link-16 to an XML representation of RDF. This same process is available for all of the other types of data, including GMTI-to-RDF, POS-to-RDF, spot report-to-RDF, and NSIF-to-JPEG[12] .

4.2.4. Information flow

So how does it all work together?

The following very simple example will help to illustrate the process. Assume that a command officer in the field wants to see all relevant ground tracks for a particular area of interest (AOI). He wants to find any providers of this information on his network, query them for all relevant detections in his AOI, and get the data back in a form he can use. The following steps will be taken in the STP environment (Fig. 4).

1. The data provider(s) and translation services come online, and register with the registry service by each sending a SOAP message (formatted as XML) to identify what it can provide and where it is located.
2. The user starts the decision desktop visualization tool.
3. The user logs into the system, thereby providing credentials which will be validated against the various data sources. He also enters into DD the specific type of information and geographic area in which he is interested.
4. By taking the previous steps, the user creates a "subscription" with the broker service. The user also can indicate the frequency at which he wants updates.
5. The broker sends a SOAP message (XML) to the registry to find all data providers that offer the chosen type of information (ground tracks).
6. The broker sends a SOAP message (XML) to the security service verifying that this user has the rights to the data provider(s). If so, then …
7. The broker issues SOAP (XML) requests to each of the data providers. In each case, if there is new information available, the broker receives ground tracks(s) in an XML message formatted as, for example, link-16.
8. Knowing that the user on whose behalf it is working needs data in RDF format, the broker sends a SOAP message (XML) to the registry inquiring about a translation service on the network that provides link-16-to-RDF translation.
9. Once the service is located, the broker sends a SOAP message (XML) to the translator requesting translation on the enclosed link-16 data.
10. The returned message containing ground track(s), now in XML formatted as RDF, is returned to the user's system which issued the initial query.

[12]NSIF is a NATO-standard format for images. As it is not widely supported by, for example, web browsers, the STP environment offers translations from NSIF to more common image formats such as JPEG.

11. The user's system makes use of the returned message in whatever way it requires; in this case, decision desktop plots the returned ground track(s) on a map.

12. Steps 5–11 continue until the user cancels the subscription. At any time, Step 1 can be repeated (a new service provider comes onto the network); when this happens the broker "learns" about it as soon as it re-queries the registry in Step 5.

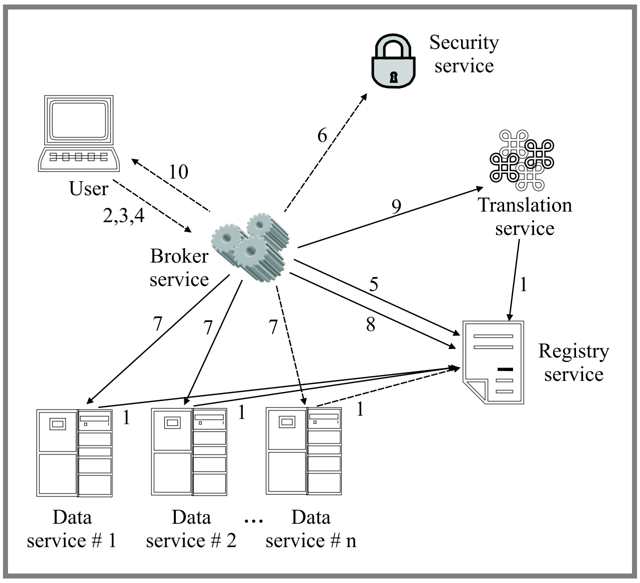

Fig. 4. The Shared Tactical Pictures environment.

These steps are illustrated in the adjacent diagram (Fig. 4). The arrows point from the initiators to the recipients of the messages.

Although this sequence of steps seems fairly simple, what's being accomplished is very powerful.

By developing a Web service interface, each of the data providers described earlier has made its information available in a common format. The flexibility of the service oriented architecture allows data sources to become available and be dynamically "discovered" by customers of that type of information. By standardizing on XML, information exchange is facilitated amongst disparate entities. Making use of the broker and translation services, the user can have information sources found and queried on his behalf, and the resultant data delivered in a format that he can use.

4.2.5. Future goals

There are some exciting additions to the STP environment in the coming months. This will include integration with some of the command and control (C2) systems taking part in the multinational interoperability programme (MIP) as they add Web services interfaces to their systems. The special requirements of deploying services to tactical users – users with low bandwidth and possibly limited viewing facilities – are being explored.

In addition, an important step will be the development of intelligent data fusion capability. It is currently possible to correlate information from a single data source. However, it would be very powerful to be able to correlate the information coming from multiple data sources, e.g., inform the user that the individual ground track being reported by sensor X is in fact the same as the ground track being reported by sensor Y. This will also be valuable in the area of blue force tracking, as different systems working together can help to identify to whom various entities belong.

Finally, there will be efforts in the future to offer a full "picture" in addition to just the ground situational awareness developed so far. This may include recognized air, maritime and environmental pictures; all Web service-enabled to take advantage of the power and flexibility of the service oriented architecture.

5. Conclusions

The shared Tactical Pictures (STP) is an important and exciting initiative in two ways.

First, it is attempting to define the policies and doctrines involved in making information available across a coalition, regardless of the source of the data.

Second, it is at the forefront of investigating the technologies of the future – service oriented architectures, XML and Web services – which will help make heterogeneous system interoperability a reality. The prototype work that has been done has already shown that ground status information can be dynamically shared from multiple, disparate systems.

The on-going work on the STP project is expected to contribute to coalition efforts for many years to come.

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