Improving Tactical Data Link Simulation Standards To Better Support LVC Exercises

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ABSTRACT*: The SwAF Air Combat Simulation Centre (FLSC) has taken an initiative called the Air Combat FOM (AC-FOM), which extends the RPR-FOM v.2.0 standard reference Federation Object Model (FOM) to better support aerial combat simulation and further enhance the level of interoperability between various internal and external simulation components. As part of the work of extending the Real-time Platform Reference Federation Object Model (RPR-FOM), FLSC has also identified a need to improve the way current standards support simulations of Tactical Data Links (TDL).*

The identified drawbacks with the current standards of simulating the Link16 TDL is that it requires a lot of effort to implement, is cost driving and is hard to use when connecting to simulation sites in other security domains. The current standards have not succeeded in attracting the Commercial off The Shelf (COTS) market in supporting it and today, as an example, very few COTS Computer Generated Forces (CGF) tools support TDL. Benefits of the current standards are however that they enable the connection with real/live systems and since Live, Virtual and Constructive (LVC)[1] *is an important requirement for the future of FLSC this needs to be catered for in future versions of TDL simulation standards.*

Another requirement, due to the need to offer a simulation capability and support training for other countries than Sweden, the TDL simulation standard should support the simulation of different TDLs without the requirement of making large changes to the simulation system. A more generic and "clear text" implementation that complements the current standards requirement for a link specific binary data array.

This paper discusses how current standards should be updated to better support the simulation requirements of FLSC and similar sites and improve interoperability with other simulation sites while maintaining interoperability with real Tactical Data Link networks.

[1] *Live, Virtual and Constructive (LVC) refers to blending real systems and people (Live) together with people operating simulators (Virtual) and forces controlled by computers (Constructive) to increase training effectiveness.*

1. Introduction

Blending Live, Virtual and Constructive (LVC) systems and simulators has become a natural element in military flight training. A full LVC training session involves exchange of entity state information such as position and speed, emitters, speech and tactical data link (TDL) messages. Examples of TDL messages are common situation picture, status reporting and orders.

This paper focuses on the TDL part. The most known TDL standard today is Link 16 [1]. Link 16 is used by many North Atlantic Treaty Organisation (NATO) organizations and NATO partners to share tactical information. Many simulators can handle Link 16 by implementing one of the existing simulation standards that support Link 16. Besides Link 16 there are other NATO links, such as Link 11 [2] and Link 22 [3] and other national links. Currently there are several simulation standards for Link 16. See "06-SIW-042 Evolving standards for TDL aware simulators" [4] for an overview of TDL simulation standards and their limitations.

This paper will discuss the motivation for a more generic way of simulating tactical data links based on current and upcoming requirements from the Swedish Air Force Combat Simulation Centre (FLSC).

2. Existing Standards That Support TDL Simulation

There are currently only a few standards for TDL simulation. These standards are mainly limited to Link 16 and have in common that they are different transport protocols for the binary Link 16 J-message format [5]. Although some of those existing SISO standards define an 'open' standard for the format of the transport, the data payload within that format is not open. The following sections give an overview of the current standards for TDL simulation.

2.1. Link 16 Over DIS

SISO-STD-002 [6] describes how Link 16 messages can be distributed over DIS [7]. This standard is often referred to as SISO-J. It extends the signal and transmitter Protocol Data Units (PDUs) with additional fields for Link 16 J-messages and metadata. The standard allows several levels of simulation fidelity by allowing that not all fields be populated if a simpler simulation is sufficient. Although the fidelity level can be adapted, the data payloads is always binary J-messages.

2.2. Link 16 Over HLA

SISO-STD-002 also describes how to distribute Link 16 over HLA [8]. The standard describes a Base Object Model (BOM) that extends the Real Time Platform v2 Federation Object Model (RPR-FOM) [9]. The extensions are the same as in Link 16 over DIS.

2.3. Link 11 Over DIS and HLA

Currently there is no finalized standard for Link 11 simulation but, there is currently ongoing work on a future standard within the SISO "Tactical Digital Information Link - Technical Advice and Lexicon for Enabling Simulation" (TADIL TALES) Product Support Group (PSG).

2.4. SIMPLE

The "Standard Interface for Multiple Platform Link Evaluation", SIMPLE STANAG 5602 [10] describes how to distribute Link 16, Link 11 and Link 22 over Internet Protocol (IP) networks. The standard is mainly used to integrate simulated TDL devices in live networks. Note that SIMPLE us its own network transport and does not run as part of an HLA or DIS federation.

3. SwAF Air Combat Simulation Centre, FLSC

3.1. Overview

The Swedish Air Force Combat Simulation Centre (FLSC) run by the Swedish Defence Research Agency (FOI) in collaboration with the Swedish Air Force, is a simulation facility for manned air combat training, education and studies. FLSC has since 1998 run simulation training courses for both pilots and fighter controllers, as well as staff personnel. The main training focus is on team based skills within the Beyond Visual Range (BVR) domain.

The simulation facility combines ten (10) manned JAS39 Gripen simulators with computer generated forces (air, land and sea). Powerful software tools are used to visualize simulation results, which contributes to more efficient training of skills and knowledges. FLSC offers large scale simulations that involve linking the facility with other similar installations around the world. Furthermore, FLSC conducts research on the effectiveness of training and performance evaluation, for example by introducing new visualizations and methods of performance measurement.

FLSC's principal customers are the Swedish Armed Forces, but the facility also has clients from other countries flying the JAS39 Gripen fighter. FLSC also provides simulation support in areas such as Simulation Based Acquisition (SBA), operational requirements, tactics development, and pre-deployment exercises.

Besides the manned pilot stations the facility includes:

- Computer Generated Forces (CGF)
- Ground Control Intercept (GCI) and Command and Control (C2) Stations
- Instructor Operator Stations (IOS)
- After Action Review (AAR) facility

3.2. Technical Solution

The simulation architecture is built on a HLA 1516-2010 federation based on the modular *RPR-FOM v.2.0* [9] which makes it possible to interoperate with other systems and extend the functionality of the facility without changing the base system.

In order to better support aerial combat simulation and further enhance the level of interoperability between various internal and external simulation components FLSC has taken an initiative called the Air Combat FOM (AC-FOM) [12], which extends the RPR-FOM v2.0 standard reference FOM. As part of the work of extending the RPR-FOM v.2.0, FLSC has identified a need to improve the way current standards support simulations of Tactical Data Links.

3.3. TDL Interoperability Challenges For FLSC

FLSC's main responsibility is tactical simulator training of pilots of the Swedish air force and other countries operating the Gripen fighter. The training focuses on operating in four group units or larger and involves heavy use of TDL simulation. One of the challenges is that not all Gripen countries use the same air TDL standard. Therefore FLSC has implemented a generic TDL format to be able to fulfill each of the customers TDL training needs.

FLSC secondary objective is to conduct training research and tactical/technical studies within the air combat domain. The simulator facility supports FOI researchers with setup and execution of sessions for varying research studies. All simulation data is recorded on a HLA object and interaction level and is combined with recordings of audio and video. Persistent storage are provided by SQL (Structured Query Language) databases which are used for data mining by the researchers of FLSC. The researchers use COTS tools including Matlab and Excel; therefore, it is important that data logging (including TDL data) is available in a clear text/numerical format (as opposed to raw J-type binary data arrays) that is directly readable by those tools.

FLSC also cooperates with external organisations connecting FLSC simulators to various external simulator facilities around the world. The interoperability relies on DIS and HLA as transport protocol. Because of classification of Link 16 or that the other facilities has had non interoperable TDL implementations, TDL simulation has not been extensively used. Instead TDL information has been distributed as plain entity state information.

In 2016 a first step to participate in a TDL enabled LVC scenario was taken by the cooperation with US Air Force Research Laboratory (AFRL) and participating in the "Cleared Hot" LVC capability demonstration at the 2016 Interservice Industry Training, Simulation and Education Conference (I/ITSEC) in Orlando Florida. During this exercise FLSC provided two Virtual Gripen fighters to the LVC scenario participating in a distributed exercise with several training facilities around the USA. The scenario included several Virtual Fighters as well as live A10-Warthog aircraft. The TDL interoperation was done through DIS with filtered and declassified Link 16 messages.

The future vision and challenge of FLSC being part of an everyday scenario where Mission Training using Distributed Simulation (MTDS) in collaboration with interoperable training sites providing virtual(V) and constructive(C) elements together with live(L) entities advocates a more generic, open, accessible and cost effective way of sharing TDL data, especially between simulation facilities, CGF tools and live platforms that are not natively TDL compatible.

4. Using Existing TDL Simulation Standards

Using the existing standards is convenient when the simulator natively support Link 16. Since the payload is binary encoded Link 16 J-messages there is no need to convert the data when exchanged to and from the simulator. Commercial off the shelf (COTS) gateways for conversion between the different standards also exist.
The SIMPLE standard is widespread in the TDL community and often used as internal transport protocol inside COTS products. The SIMPLE standard however does not use a standardized simulation infrastructure such as DIS or HLA and therefore require separate network for transport.

5. Motivation For Open Standards

The current standards för TDL simulation are not widespread today and support very few data links. When working with HLA and DIS, SISO-J is currently the only useful standard.

5.1. Proprietary Solutions

Current standards are complex to implement and often too extensive for many simulators. If the simulator does not support Link 16 natively translation will be required from the simulator's own TDL message format to J-messages. Translation are error prone and would be unnecessary if the other simulators connected use the same TDL implementation. As a result many simulators run with various TDL implementations that are not interoperable. An open standard for TDL simulation would decrease system complexity, reduce the data processing overhead and eliminate reliance on proprietary solutions.

5.2. Foreign Customers

Many countries do not operate or have access to Link16 and access to Link 16 specifications is tightly controlled so permission to use Link 16 is limited to relatively few countries. Consequently, many countries operate national tactical data links of their own design. In many ways, these country-specific TDLs function similarly to Link 16 but use different binary data packages and transport protocol. Since there is no standard today for simulation of those national links they are differently implemented from simulator to simulator, making it difficult or impossible for simulators from different countries to interoperate.

5.3. Commercial

The Link 16 standard is restricted for use by commercial companies, and products based on Link 16 are impeded by export laws. The interest from commercial companies and organizations has been minimal and few COTS tools support tactical data link simulation. With support for open standards there will be a larger interest from commercial companies and the community of governments and industry to develop tools that support TDL simulation. An open standard for simulation purposes would cause an increase in tools such as:

- Gateways
- CGFs
- Code generation tools
- Analysis tools

5.4. Registration And Analysis

Registration and analysis of binary formats, such as the format currently defined in SISO-J standard is inconvenient when data shall be analysed and displayed by third party tools. An open format would allow for a broad support from multiple private and commercial registration and analysis tools.

5.5. Security

By using a standardized and generic TDL implementation it will be easier to analyze security aspects. Since the data is in an open, well structured format, security implications can easily be discovered and allow for simplified design and application of appropriate data filters. By using an accredited gateway that filters data according to current policies it will be possible to connect systems from different security domains without the need of modifying existing systems.

6. LVC With A Generic Tactical Data Link

A full LVC training session involves several components that might exchange tactical information over a tactical data link. Example of a typical LVC setup is described below.

6.1. Live Entity

The live entity is a real platform operated by a real operator. The live entity has either a NATO tactical data link or a national data link and is communicating through a radio or IP network. A live entity typically has a real operational link. Usually the possibility to make changes to the live system is very limited or nonexistent.

6.2. Virtual Entity

The virtual entity is a simulated platform operated by a real operator. It could be a full vehicle simulator or a lesser capable (lower fidelity) desktop simulator. In the case of a full vehicle simulator, it is likely that the simulator can handle the native messages of the tactical data link. In that case, one of the existing TDL standards can be used.
If the virtual entity is a low fidelity desktop simulator, it likely does not fully support the native TDL messages, in which case the simulator could use a generic open TDL simulation standard.

6.3. Constructive Entity

The constructive entity is a simulated platform operated by a simulated operator. A collection of constructive entities is often referred to as Computer Generated Forces (CGF). It is common to simulate more than one constructive entity in one simulator. The fidelity level of a CGF is usually lower than for virtual entities. It is common that CGFs are embedded in COTS tools. Some of these tools support TDL simulation with real tactical messages while others are more generic and could use a standardized generic link simulation.

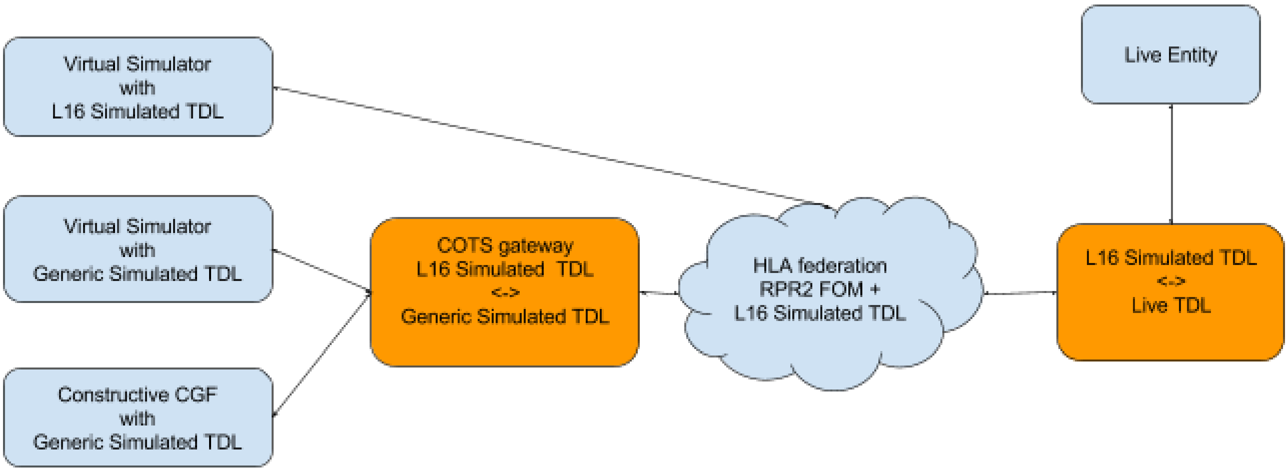

Figure 6.1 LVC type configuration using TDL for data exchange between different systems.

6.4. Benefits

There are several benefits from a standardized generic TDL when operating a LVC session. A standardized generic data link would make it possible to take advantage of third party TDL enabled CGF tools. It would enable use of third party bridging software between different data links.

7. Design Of An Open TDL Standard

When designing a generic TDL standard a lot can be gained by making it in a way that it supports several data links, not only one link like for example Link 16. This section describe likely requirements on such a data link and some initiatives that has already been taken by different organisations.

7.1. Requirements

An already existing simulation data distribution mechanism should be used. There's no need to invent a new way of distributing data link data between subscribing systems and models. That would also allow for a future SISO Product

Development Group to focus more on the challenge of representing a generic data link in simulation than the implementation of a new simulation data distribution approach. The two most broadly used approaches known today is HLA and DIS where HLA has the benefit of supporting domains outside of the defence sector. Both HLA and DIS are both already used to support LVC events. The HLA FOM format is a very good way of defining a data model and tools exist that support a more visual analysis of its structure. The possibility to do future extensions while still being backward compatible is highly desirable and the hierarchical nature of the FOM allows it to support many fidelity levels at the same time. In order to allow for the development of COTS tools that support the standard it is highly desirable that the standard avoids using or referring to any standards or data that is limited by export control or any other limiting factors and use a clear text message format that can be easily decoded by third party tools. Ideally the standard should be easy to understand and implement and avoid using complex data or non standard data formats for expressing for example distance. The standard must also support the use of gateways to transfer between generic and real data link subscribers so that virtual and constructive simulators, where there's no need to implement support for the real data link, can share data link data with live real data link subscribers.

7.2. Initiatives Towards A Generic TDL Simulation Standard

There is currently work underway to among companies and organizations to look at how to build a standard for a generic TDL simulation. Below are some of the promising initiatives described.

7.2.1. FLSC Air Combat FOM

FLSC in cooperation with other Swedish defense companies has proposed and implemented and national standard FOM for generic TDL simulation. The FOM is called the Air Combat reference FOM (AC FOM) and extend the RPR-FOM v.2.0 with functions to better support air combat simulation. A part of this FOM is a generic TDL module that support Link 16 and national data links (AC-Link). This proposed standard is not yet released outside of FLSC.

7.2.2. Diginext LinkX Proposal

The French company Diginext is specialized on TDL simulation and testing. They have several COTS products that support TDL simulation, including the SISO-J and SIMPLE standard. Diginext has identified the need for generic tactical data link and has proposed a design called Link X [11]. Link X is a generic data link message format that support the current tactical data links in use, and many other national data links. The goal is to produce a TDL implementation that does not require deep knowledge of current TDL standards to implement. Link X mainly define the message format and structure the messages. The transport layer is open and can be, for example, an HLA FOM or DIS PDUs. Complicated TDL details such as crypto and network setup is not part of the Link X proposal. The idea is to let the community and commercial market build gateways that can translate Link X to TDL simulation standards and live TDL systems.

8. Conclusion

The main reason to develop an open generic TDL standard is to enable third parties to produce standardized tools that support TDL simulation, and in the end make it simpler and more cost effective to work with TDL simulation. We especially see the benefit in the area of CGFs and TDL bridging software.

A generic TDL would enable cost effective LVC exercises that use a minimum of proprietary systems. Live systems will still use real TDL implementations since those are hard to change and would require non simulation friendly solutions to distribute the link data and use protocols optimized for their operational environment.
Simulation facilities do not have those limitations and can more freely choose how to distribute and simulate TDL without adding the expensive overhead of using real TDL systems.

Our suggested solution is to let virtual and constructive systems use generic TDL and use COTS/GOTS gateways built around the generic TDL standard to interoperate with live systems.

A standard defining generic TDL simulation would drive organizations and commercial companies to build products that let live, virtual and constructive systems interoperate in a standardized and cost effective way.

A typical example where this need arise is FLSC that cannot today implement their desired TDL architecture using Link 16 only. FLSC must be able to interoperate with both L16 enabled systems and other system with national data links without changing the simulator system.

There are currently several promising initiatives to develop such a standard. To establish a usable standard we propose to initiate a SISO study group to capture the work already done towards interoperable TDL simulation.

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