Tactical Data Links in a C2SIM Environment

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ABSTRACT: *Tactical Data Link (TDL) are a set of standards for Command and Control (C2) Systems to continuously exchange operational situations, orders and reports with other C2 or TDL enabled platforms such as fighters or ships.*

This paper focuses on proposing an approach for efficiently stimulating one or many C2 systems with a simulated complex tactical environment using the TDL interfaces of the C2 System. It relies on the ongoing work made by the C2SIM Product Development Group (PDG) of the Simulation Interoperability Standards Organization (SISO). C2SIM standard which is under development aims to ease C2 and Simulation interoperability improving both the previous SISO-STD-007-2008 Standard for Military Standard Definition Language (MSDL) and the SISO-STD-011-2015 Standard for Coalition Battle Management Language (C-BML). It is proposed to develop a C2SIM TDL extension to define a standard and straightforward way of exchanging TDL messages between simulations / simulators and C2 systems.

Such an extension is intended to focus on TDL functions and not to detail technical mechanisms of real TDL implementations. The purpose is to make it accessible without a significant technical TDL knowledge. The approach relies on the definition of a data model, called LinkX, which defines the set of common services, messages, types and dictionaries reflecting the main concepts of the different TDL implementations (Link 11, Link 16, Link 22, VMF, etc). This data model is proposed to be implemented as a C2SIM extension.

This paper first describes the background information about the use of TDL in simulations which illustrates the needs for the proposed approach. The LinkX data model is then presented with the methodology used to design it. The paper provides early feedbacks about the preliminary implementation work of this data model as a C2SIM extension based on preliminary versions of the standard, and introduces the experimental components that was reused, enriched and developed to assess the extension.

1. Introduction

Tactical Data Link (TDL) standards are currently supported by Air, Navy and some of the Army C2 Systems.

Figure 1 provides a simple example of some of the TDL capabilities between a Link 16 C2 System embedded in an Air Carrier and two Link 16 fighters.

Figure 1 - Vignettes of the first technical scenario

Importance of Tactical Data Link is increasing in current and future operations and particularly in joint or multinational operations as in addition of being a factor of superiority it is a key factor of improving operation safety. To illustrate the importance of TDL, the support of Link 16 standards can be required for national platforms, to participate to certain NATO operations.

Testing such C2 System or training operators of such C2 Systems, requires the presence of a real tactical environment which can be very complex and expensive to deploy (real friendly and hostile platforms, C2 systems,

TDL radio networks etc.) or simply not possible to be deployed by a single nation.

Simulating such tactical environment with a constructive simulation is an attractive alternative as it results in simplifying a lot the organization of a training or testing session as no live environment is required. However, implementing the TDL standards (NATO STANAG/ US MIL-STD) is tedious and requires a high level of TDL expertise. Those difficulties raised as new editions of the standards are adopted and result in creating additional complexity because TDL platforms may interact with large number of different TDL editions.

With this increasing demand and complexity, there is a need to find a solution to ease integration of TDL with simulations/simulators in order to simplify the architectures of Live, Virtual and Constructive training solution and to support more efficiently the use of simulation for design and acquisition of future TDL enabled systems.

2. Previous work

Few simulation and simulator systems have currently implemented TDL capabilities except certain full flight trainers. Most of the time the approach that can be observed is one of the following 3 solutions using:

- the real Link 11 [6] or Link 16 [4] STANAG encapsulated in the SIMPLE [8] protocol ;
- the SISO-STD-002-2006 [7] or SISO-STD-005 Draft [9] Standard;
- a proprietary implementation of a functionally equivalent TDL.

The first approach is to use the STANAG 5602 (SIMPLE) [8] to transmit TDL messages on an IP Network. The SIMPLE standard provides a common way for the interconnection of ground rigs of all kinds simulations, integration facilities etc.. SIMPLE was initially developed for testing TDL systems and consists of encapsulating real TDL packets as well as others types of packets such as Distributed Interactive Simulation (DIS) packets and transmitting them on a Local Area Network (LAN) through the Internet Protocol (IP). This approach is straightforward as far as the connected systems need to fully support compatible TDL implementations. Therefore, the approach requires encoding properly all the messages and needs to comply with the complex rules of the supported TDL implementations.

The second solution is to use SISO-STD-002-2006 [7], which is a standard for transporting Link 16 messages (also known as SISO J) over the DIS or High Level Architecture (HLA) simulation standard. Similar initiative exists for Link 11 with the SISO-STD-005 Draft [9] standard describing how to encapsulate M series messages (known as SISO M). Both approaches require a strong Link 11 or Link 16 background as they rely on real J and M message encoding and therefore the degree of implementation complexity for a simulation or simulator is comparable with the SIMPLE STANAG implementation.

The last approach is to adopt a proprietary "functional TDL", consisting of simulating TDL exchanges without any consideration of the message encoding issues and complex TDL rules of emissions. This approach has been successfully used by several simulators with the main drawback that simulators will not be able to interoperate with other systems unless the proprietary definition of the functional TDL has been published. At this time, there are no proposed standards for defining such functional TDL.

C2SIM [2] is the proposed SISO [10] standard to overcome interoperability issues between simulation and C2 systems. This standard is being developed to build a coherent approach that will merge and replace both the SISO scenario initialization standard (MSDL [12] - Military Scenario Definition Language) and the SISO Tasking/Reporting standard (C-BML [13] - Coalition Battle Management Language). C2SIM intends to address some of the drawbacks raised by predecessors and to propose a solution based on a core logical data model (LDM) and an extension mechanism.

Hence, the intent is to propose a standard data model for defining a functional TDL that could represent any of the existing Links such as Link 11 or Link 16 but also that could be easily extended to design futures TDL, and to implement it as a C2SIM extension mechanism. Similar initiative [1] is also proposed with the focus of using an HLA Federation Object Model (FOM) extension for transmitting the same functional TDL over HLA so that such TDL can be either simulated and transmitted between different HLA simulation federates or transmitted between C2SIM enabled C2 or Simulations.

3. LinkX: a functional TDL

The first LinkX data model version designed was initially developed based on DIGINEXT previous experience in

implementing TDL tools for tests and developing constructive and human in the loop simulations. The scope was to natively introduce into homemade constructive simulation software, called DirectCGF, the capability to simulate complex operational theaters with platforms equipped with functional TDL devices. This work consisted in analyzing the current TDL standards and defining a selection of common useful services without implementing the complete STANAG or MIL-STD.

First, it was decided to distinguish two types of TDL unit: the C2 (Command and Control) units and the NC2 (Non Command and Control) units as they implement different types of services. The C2 units are associated to platforms or facilities that can play the role of a controlling system such as Airborne Early Warning & Control platform (AWACS) as opposed to NC2 units that can be associated to non controlling platforms such as a Link 16 fighter.

The services have been divided into the following areas:

- Surveillance services: all activities possibly transactions between any participant and related to maintaining the tactical situation such as Participant Location and Identification information (PPLI), the detections, tracks and messages reported by the local and remote sensors etc.
- Command services: all activities related to C2 to C2 transactions such as guidance order or threat warning.
- Control services: all activities related to C2 to NC2 transactions (or NC2 to C2) such as Taking/releasing control, Flight plan, Mission Assignment etc.

This work resulted in defining a set of messages associated with the different services.

Surveillance (all units)	Command (C2 to C2)	Control (C2 to NC2 or NC2 to C2)
PPLI	Guidance Order	Control change
Internal Detection		
Remote Transmission		
Battle Damage Status		
Resource State		
Correlation	Threat warning	Flight Plan
Drop		
Emergency Point		Mission Assignment
Free Text		
Pointer		
Reference Point		

Figure 2 - Proposition of LinkX messages for the Surveillance Command and Control services

The messages have then been designed in detail by defining for each of them their attributes and associated types and range of values for the enumerated types. The resulting logical data model is currently made of 16 messages, 16 elementary types and 20 enumerations.

The messages have been implemented in DirectCGF simulation which was also extended with models to support the composition and transmission of the TDL messages and the underlying logic of command and surveillance services. The Figure 3 shows, in the red circle, the composition of a LinkX Mission Assignment message by a simulated AWACS operator addressed to a LinkX fighter as implemented in DirectCGF.

Figure 3 - Composition of a LinkX "Mission assignment" within DirectCGF

The evaluation, mostly experimental, was to create Air Surface Operation scenarios including various types of missions. The resulting LinkX model was robust enough to implement different scenarios such as DACAS (Digitally Aided Close Air Support), COMAO (Composite Air Operations), ASFAO (Air Support Force Air Operation) and SEED DEAD versus access denial systems.

Once the LinkX model was defined and implemented in DirectCGF simulation, it was required to identify solutions for transporting the LinkX messages over a network so that distributed simulations and real or emulated C2 systems could exchange TDL information. Hence, two different approaches were assessed. The first one introduced in [1] consisted on working on the definition of a FOM extension for HLA. This approach is focusing on TDL interoperability between simulations where many TDL platforms hosted by many simulations can agree on the way to exchange and interpret TDL information. The second approach introduced in the following section consists on proposing a C2SIM extension for the LinkX. Such approach provides interoperability layers for C2 systems and simulations so that real or emulated C2 can exchange TDL messages with one or many TDL platforms hosted by one or many simulations.

4. LinkX as a C2SIM Extension

Numerous reasons for implementing LinkX as a C2SIM extension motivate this approach.

First, the objective of the C2SIM standard perfectly matches with the challenge of facilitating and standardizing interoperability between C2 and simulations. The solution proposed by C2SIM, as opposed to C-BML and MSDL, is based on a core data model, called C2SIM-Logical Data Model (LDM), which "provides at a logical level, a core set of data elements common to most C2 and simulations systems combined with a standard way of adding to that core a collection of additional elements specific to a particular domain and/or context" [2].

Second, the proposition of implementing a TDL extension on top of the C2SIM-LDM is a challenging way of assessing the LDM and its extensibility as TDL modeling is not the primary focus of the standard. The success in implementing the LinkX extension would show the versatility of the standard. The definition and assessment of the TDL extension has been reported through the NMSG-145 NATO working group [3].

In order to define the C2SIM extension iteratively, an engineering process supported by the selection of the NATO Architecture Framework (NAF) and UML Views was chosen. The process presented in Figure 4 was adopted mainly for two reasons:

- Challenging initial LinkX implementation with a strict engineering process based on various set of operational scenarios;
- Adopting an iterative process in order to successively improve and refine the LinkX definition as new

operational scenarios are developed.

Figure 4 - Engineering process for the LinkX C2SIM extension design

The process has been currently executed with a first technical elementary scenario involving a C2 system (Aircraft Carrier), two friendly fighters and one hostile fighter.

The process first iteration execution results in providing a LinkX logical information model consisting of a set of 6 different types of messages based on 8 elementary types and 7 enumerated types:

- ControlChange: message sent when a NC2 unit takes or releases control over a C2 unit ; Messages used in Link 16 : J12.4, J10.5 ;
- PPLI (Precise Participant Location and Identification): message sent by a C2 or a NC2 participant to provide its current state information at a regular rate ; Messages used in Link 16 : J2.2, J2.3 ;
- InternalDetection: message sent by a C2 or a NC2 participant to provide an internal detection ; Messages used in Link 16 : J3.2, J12.6 ;
- RemoteTransmission: message sent by a C2 participant to provide a remote detection ; Message used in Link 16 : J3.2 ;
- Correlation: message sent by a C2 participant to an NC2 to provide correlation information ; Message used in Link 16 : J12.5 ;
- MissionAssignment: message sent by a C2 participant to a controlled unit in order to assign a specific mission ; Messages used in Link 16 : J12.0, J10.2.

Link 16 messages exchanged for each vignettes of the Figure 1 are:

- Vignette 1:
 - PPLI broadcasted by friend fighters with J2.2 messages.
 - PPLI broadcasted by the Aircraft Carrier with J2.3 messages.
- Vignette 2:
 - Detection of an hostile fighter by the Aircraft Carrier, the message J3.2 is sent by the Aircraft Carrier to a friendly fighter and other C2 units over the Link 16 Network.
- Vignette 3:
 - The Aircraft Carrier takes control the friendly fighter with a J12.4 message.
 - The Aircraft Carrier broadcasts to other C2 units that he has the friendly fighter under control with a J10.5 message.
 - The Aircraft Carrier sends a Mission Assignment Discrete message, J12.0, to the friendly fighter to assign a Visual identification of the hostile fighter.

- The Aircraft Carrier broadcasts to other C2 units the Weapon Engagement Status of his friendly fighter under control in function of the previous mission assignment with a J10.2 message.
- Vignette 4:
 - The friendly fighter detects the hostile fighter with his own sensor and sends a J12.6 message to the Aircraft Carrier.
- Vignette 5:
 - The Aircraft Carrier correlates the friendly fighter detection with his own detection and sends a J12.5, correlation message, to the friendly fighter.
- Vignette 6:
 - The Aircraft Carrier sends a new MAD, J12.0, Return to Base to the friendly fighter.
 - The Aircraft Carrier terminates the control with a J12.4.
 - The Aircraft Carrier broadcasts to the other C2 units the end of the control of the friendly Fighter.

When confronted to the early drafts of the C2SIM-LDM the resulting LinkX logical information model confirmed that the C2SIM extension mechanism was mostly compatible with first DIGINEXT proprietary LinkX data model. Mostly two issues were highlighted:

- Certain basic C2SIM LDM types were missing to handle third dimension entities for example position of entities where defined in two dimensions (latitude and longitude but no altitude);
- Some C2SIM enumerates were very similar to LinkX enumerates but had to be extended, and no mechanism to extend enumerates were present in the C2SIM LDM.

The implementation of a first version of the LinkX extension will end as soon as the first version of the C2SIM LDM will be released. It will be assessed within the demonstration described in the following section.

5. Demonstration

The demonstration is based on a constructive simulation, DirectCGF, which was modified to publish the LinkX messages using the C2SIM extension. It is also required to develop an experimental gateway to translate C2SIM LinkX messages into equivalent real Link 16 messages encapsulated using SIMPLE in order to address interoperability with a legacy C2 Link 16 system. More complex is to introduce a human in the loop simulator that also implements the C2SIM LinkX interface.

The Figure 5 provides an overview of demonstration components.

Figure 5 - Demonstration for evaluating the LinkX C2SIM extension

Within this framework all simulated entities (C2 or NC2) equipped with LinkX devices and hosted by the constructive simulation might be able to use the Command (if C2), Control (if C2 or NC2) or Surveillance services (if C2 or NC2) to interact with the real C2 unit through the experimental gateway. The NC2 units of the Constructive simulation or the real C2 system might also use Control or Surveillance service to interact with the Virtual Fighter. Therefore, the demonstration provides the means to execute a large range of use cases that could ease the assessment (performance, agility ...) of the approach and particularly to identify the most relevant end users applications.

6. Conclusion

The work highlighted within this paper describes the C2SIM extension process for a generic Tactical Data Link, called LinkX with the main objective of enabling the capabilities of simulation to interoperate with C2 Systems supporting TDL to exchange orders and tactical situations with reports. Applications of the LinkX are multiple as it can be used:

- to train C2 operators in simulated tactical environments of scaling complexities;
- to stimulate and stress a C2 System in a simulated tactical environments of scaling complexities for testing purpose;
- to support the definition of a future or domestic Tactical Data Link.

The demonstration to assess the C2SIM TDL extension has proven the usability of the LinkX C2SIM approach. The Engineering process execution in addressing armed forces critical use cases will furthermore demonstrate the effectiveness of the extension mechanism.

7. References

- [1] Evolving Standards for Tactical Data Link Aware Simulators Patrik Svensson, Stefan Sandberg, Fredrik Antelius, Laurent Ferriani, Laurent Mounet, Proceedings of 2016 Fall Simulation Interoperability Workshop, 2016-SIW-042, Simulation Interoperability, Standards Organization, September 2016
- [2] "Standard for Command and Control Systems - Simulation Systems Interoperation", first draft of the consolidated document, SISO C2SIM PDG, May 2017

- [3] "Program of Work of NMSG-145", NATO MSG-145, March 2011
- [4] "Tactical Data Exchange - Link 16", NATO Standardization Agency – STANAG No. 5516, Nov 2008
- [5] "Tactical Data Link (TDL) 16 Message Standard", Department Of Defense Interface Standard - MIL-STD-6016 Revision C, March 2004
- [6] "Tactical Data Link (TDL) - 11/11B Message Standard", NATO Standardization Agency - STANAG No. 5511, February 2006
- [7] "Standard for Link 16 Simulations", SISO Link 16 Product Development Group (PDG) - SISO-STD-002-2006, 10 July 2006
- [8] "Standard Interface for Multiple Platform Link Evaluation (SIMPLE)", NATO Standardization Agency – STANAG No. 5602, July 2010
- [9] "Standard for Link 11/11B Simulation", SISO Link 11/11B Product Development Group (PDG) - SISO-STD-005-V9 Draft, september 2010
- [10] "SISO – Simulation Interoperability Standards Organization",
<https://www.sisostds.org/AboutSISO/Overview.aspx>
- [11] "HLA – High Level Architecture", https://en.wikipedia.org/wiki/High-level_architecture
- [12] "MSDL – Military Scenario Definition Language",
https://en.wikipedia.org/wiki/Military_Scenario_Definition_Language
- [13] "CBML – Coalition Battle Management Language",
https://en.wikipedia.org/wiki/Battle_management_language

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ERIC BOUVIER is the head of the Business Development department at Diginext. He has about 20 years of experience in the development of simulation software particularly for the defence sector. Before joining Diginext in 2001, he has been director of development of a video game company where he has led the development of Virtual skipper sailing simulation game. Before, he worked as expert researcher in CRS4 (leading Italian research Institute in Computer Graphics), and head the development of an award winning crowd simulation software in California. Eric obtained his Ph.D. in computer science in 1997 at University Paul Sabatier in Toulouse developing algorithms and models for crowd simulation

LAURENT MOUNET is one of the technical backbone of the Business Development department at Diginext. He has more than 15 years experiences in the development and the interconnection of Tactical Data Links systems. During this period he developed different TDL Multi-link gateways and additional features in the gold reference TDL Test Tool, TactX. He was also head of the Customer Care team and since 2015 he joined the TDL Expert Team in the BD department. He has participated at leading French, NATO and US Exercises around the world such as CWIX in 2014 and 2016 in Poland and Boldquest in 2015 in USA.