Evolving Standards for Tactical Data Link Aware Simulators

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ABSTRACT: *The ability to simulate Tactical Data Links is becoming increasingly important in order to more accurately represent the modern battlespace. There is also a need to be able to connect with or simulate commercial use data links such as ADS-B and AIS. LVC applications may rely on the integration between simulation systems and real data links in order to integrate live entities into a simulated scenario in applications ranging from test and evaluation to training. There is also a growing number of COTS simulation tools available that support integration with data links.*

This paper will discuss the need for inclusion of a data link FOM module in the upcoming RPR-FOM v 3.0 which supports various data links such as Link 11, Link 16 and the upcoming Link 22. The paper also discusses the need for supporting a more generic interaction with data links that would enable integration of various simulation CGF components with less effort and enable COTS tools to evolve with a broader support for different data links.

1. Introduction

There is currently an increasing demand for Tactical Data Link (TDL) simulation in various military and civilian High Level Architecture (HLA [1]) enabled simulators. Many of these simulators implement their own Federation Object Model (FOM) extensions to enable TDL simulation, which make them non interoperable with other simulators. This paper discuss the demand for a standard for a more generic way of representing datalinks in various types of simulators. The standard might be added as a module to the upcoming version 3.0 of the "Standard for Real-time Platform Reference Federation Object Model" (RPR-FOM [2]).

This paper does not aim at presenting a complete solution for a TDL FOM module, but to investigate the limitations of the implementations available today and present a direction for a new TDL FOM module.

2. Overview of Tactical Data Links

A tactical data link use a data link standard to provide communication via radio waves or cable. The data link is used to transmit, relay and receive tactical data between command and control (C2) systems. There are several legacy and current TDL standards. The most well known standard today is probably Link 16 (STANAG 5516, MIL-STD-6016) that is widely used in military operations. Since TDL:s is an integral part of modern military systems the demand for data link training in simulators is increasing.

Since there is a large amount more or less well known TDL:s, the information that can be distributed on a these links will vary but there there are some information that can be seen as core functionality in TDL:s:

- Reporting of own position and status
- Reporting of target detections
- Order handling
- Navigation aid

2.1. TDL standards

There are both national and international TDL:s. International TDL:s are described by well defined standard documents. I.e Link 16 is defined as a Nation Standard Agreement (STANAG) document available to NATO countries and other approved nations and organizations. Since TDL:s are mostly implemented as radio networks the physical transport and encryption is a major part of the standards. From a simulator software point of view the physical transport is of less interest, but the content of the tactical messages are more important. To be able to implement a simulator, knowledge of the content of the TDL messages must be known, and how they are encoded.

Simulator systems many times do not include real radio hardware and alternative physical transport is needed. I.e Link 16 has the supporting standard SIMPLE (STANAG 5602) that describe how to distribute Link 16 messages over Ethernet networks.

3. Example of TDL:s

Even though TDL:s are most commonly used in military systems there are are civilian data links that have similar functions as TDL:s. The common factor is that they provide a “tactical” situation picture. This chapter describes a selection of TDL:s and their characteristics. Most of the information in this chapter is extracted from references [3], [4] and [5].

3.1. Link 16

Link 16 (STANAG 5516 [6], MIL-STD-6016 [7]) is a NATO standard tactical data link. Link 16 enable participants to exchange tactical situation in near real time. It also supports text messages, imagery and digital voice. It is based on “time division multiple access” (TDMA), it is encrypted and jamming resistant. It is line of sight dependant but can be extended with relaying by radio or ethernet.

Physical radio transport is done with standardized hardware “Multifunctional Information Distribution System” (MIDS). MIDS terminals are available in several versions depending on the platform it is installed on.
Link 16 is today the prominent link on Nato vessels and aircraft, but also in use by non NATO countries. Tactical messages are transferred as fixed format standard J-series messages.

3.2. Link 11

Link 11 (MIL-STD-6011 [8]) is an encrypted half duplex tactical data link used by NATO. It was initially used for naval operations, but is now also used on airborne and land-based systems. It is primary used is to exchange radar tracking information. Link 11 is based on 60:s technology and will eventually be phased out, but will probably live on for a long time, and the need to be able to bring Link 11 systems to distributed simulations will still be needed. TDL messages are exchanged on the M-series message format.

3.3. Link 22

Link 22 (STANAG 5522 Draft) is an upcoming tactical data link that will eventually replace Link 11 and complement Link 16. The goal is to create a link that improve allied interoperability and improve the tactical view for commanders. Like Link 16 it will use TDMA for sender time slot allocation. There is no central node in the network but initial setup will require a common time reference and planning of link member id:s. The link will be encrypted and support beyond line of sight operation. The tactical data will be transferred as the same fixed format J-series messages as in Link 16. This will provide interoperability between Link 22 and Link 16. Link 22 will use both the J-messages from Link16 and it’s own FJ-series messages which are enhanced versions of Link 16 messages or messages that do not exist in Link 16.

3.4. ADS-B

Automatic Dependent Surveillance Broadcast (ADS–B) is a civilian broadcast data link that is used by air traffic control to retrieve information about aircraft position, speed and identification. ADS-B can replace or complement secondary radar and transponders for air traffic management.

ADS-B messages are broadcasted periodically in a well known format and received by ground stations giving a situation picture. The link messages are encoded as 65 bit messages according to the Mode S Extended Squitter format, also know as VDL Mode 4. Since ADS-B data is not encrypted it can be received by consumer grade products and used to provide real time air traffic to simulators. A common output format from ADS-B decoders is the Basestation format [9]. ADS-B is the data link that power Flightradar24 (https://www.flightradar24.com).

3.5. AIS

Automatic Identification System (AIS) is a civilian broadcast data link that is used by maritime vessel traffic services (VTS) to locate and identify maritime vessels. Sender allocation is done with self organizing TDMA (SOTDMA) which provide a network with no need for initial setup or central nodes. AIS messages are encoded according to the open National Marine Electronics Association (NMEA) standard and contain information about position, speed, course, identity and status. Like ADS-B, AIS messages can be received by consumer grade products and used to provide live maritime traffic in simulations. AIS is the data link that power Marinetraffic (http://www.marinetraffic.com)

Link	**Message format**	**Type of link**	**Purpose**
Link 11	M-messages	Half duplex secure tactical data link	Distribute radar situation picture
Link 16	J-messages	Full duplex secure LOS tactical data link	Distribute situation picture and orders
Link 22	FJ-messages F-Messages	Full duplex secure BLOS tactical data link	Distribute situation picture and orders
ADS-B	Mode S Extended Squitter	Unidirectional broadcast data link	Provide own position to ATC
AIS	NMEA	Unidirectional broadcast data link	Provide own position to VTS

Table 1: Summary of common TDL:s

4. Current Support for TDL Simulation

Today there are a few standards available for TDL simulation. They are all based on the Link 16 standard and do not support other TDL:s. They all have in common that they encapsulate the raw J-messages in another transport protocol. This makes it convenient to make simulators interoperate with real Link 16 hardware since no translation of the TDL messages is needed. These standards focus on how to interoperate with Link 16 networks with respect to time slots and link membership and not how to encode or decode messages.

4.1. Link 16 over DIS

The SISO "Standard for Link 16 Simulations", also known as SISO-J (SISO-STD-002 [10]) describe how Link 16 can be transmitted over the "IEEE Standard for Distributed Interactive Simulation" (DIS [11]). The standard define how to populate the Transmitter and Signal PDU:s to simulate Link 16. The structure of the PDU:s are unchanged from the DIS standard but but new types and interpretations have been added. Link 16 specific information is handled in variable length fields.
Modelling of Link 16 can be done at multiple fidelity levels depending on the demand from the participating simulators.

4.2. Link 16 BOM

SISO-STD-002 also describe an object model for Link 16 simulation over HLA. It is presented as a Base Object Model (BOM) extension that can be included in an existing RPR-FOM v2 Federation Object Model (FOM). The BOM adds the same information as in the DIS Protocol Data Units (PDU:s) for Link 16 to the RadioTransmitter object and the interactions derived from RawBinaryRadioSignal.

Note that the since the BOM was developed before modular FOM:s where available, is not an HLA Evolved FOM module and cannot be loaded as such in a modular FOM. It must but must be manually added to the FOM. A major improvement would be to develop a modular version that can be loaded as an HLA Evolved FOM module.

4.3. Standard Interface for Multiple Platform Link Evaluation

The "Standard Interface for Multiple Platform Link Evaluation", SIMPLE (STANAG 5602 [12]) is a communication standard for distributing Link 16, Link 11, Link 22 and other TDL messages on IP networks. It can be used to integrate non radio devices and simulations with Link 16 and to extend Link 16 beyond line of sight. TDL messages are extracted from one TDL terminal and encapsulated in the SIMPLE protocol. On the receiving side the data is extracted from the SIMPLE protocol and fed to the receiving TDL terminal.

The SIMPLE protocol consist of several elements including communication bearer, encryption, data formats and time coordination.

4.4. Limitations with available TDL simulation standards

There is currently support for Link 16 and other data link simulation through encapsulation of the the raw TDL messages in SIMPLE and SISO-STD-002. These standards have put much effort in providing a useful representation of the Link 16 physical properties while maintaining the tactical message format unchanged from physical Link 16. This is an advantage when interoperating with real hardware and Link 16 aware system but a drawback when working with non Link 16 aware systems. Non Link 16 aware HLA simulation systems need a FOM to describe the common data model used to exchange information. The FOM describe what data types that is used and how the data is structured. All simulation systems that use the same FOM will be able to communicate with each and have the same view of the data model. To make the simulators fully interoperable the FOM need the be generic, that is all data must be in a generic format. Binary data thas is not fully described by the FOM will break the interoperability provided by a FOM.

The major limitations with the current standards are:

- The Link 16 specification is classified as “NATO Unclassified” which mean that is not open to the general public and hence the specification on how the tactical data messages are encoded is not available. This makes it impossible for third party companies to build simulation tools that can interoperate with Link 16.
- The SIMPLE specification is is classified as “NATO Unclassified” which mean is is not open to the general public.
- The current standards does only support a selection of military TDL:s and cannot handle other civilian links such as ADS-B

These limitations make or impossible to create generic interoperable link aware simulators.

5. Generic Data Link Simulation

The existing SISO-STD-002 already model the physical characteristics of the Link 16 but does not support simulation of a generic tactical data link. To be able to bring tactical data link simulation to a broader range of platforms a generic TDL simulation FOM module and standard is needed.

Requirements on such a standard are:

- Open standard available without restrictions for everyone
- No use of proprietary or closed data formats
- Easily decodable data format - possible to debug and record
- Support for the at least the most common TDL:s today:
    - Link 16
    - Link 11
    - Link 22
    - ADS-B
    - AIS
    - Generic data link
- Different fidelity levels making it possible to integrate low fidelity simulators such as CGF:s
- Distributed as HLA Evolved FOM module

The introduction of a TDL FOM module will make it possible to create generic link aware simulators that can interoperate with each other with basic TDL messages. If interoperability with more advanced data link implementations such as SIMPLE a common gateway can be created that translate between SIMPLE and the generic TDL: format.

5.1. Common data in TDL:s

The challenge when creating a generic data link is to find the data common between different TDL:s**.** Even if it would be possible to create one generic link message type containing all information that would make it almost impossible to work in practice.
TDL messages can be categorized in different areas of interest:

- Reporting own position
- Reporting status
- Reporting tracks
- Reporting surveillance

- Sending orders
- Sending information (weather, points)
- Sending warnings
- Track management
- Target coordination and weapons management

For each category of messages there will be a base class with generic information and several extension classes supporting link specific parameters.

Below is an example with reporting of own position. In Link 16 the J3.2 Air Track is used to report the position and speed of a Link16 track. In ADS-B message type 3+4 are used to used to report the position and speed of a civilian aircraft. Looking at those two messages from two very different TDL:s we can see that they have quite a lot of parameters in common. Position, altitude, speed, course and callsign are used in both TDL:s. Besides the common parameters there is data that is specific for each TDL. In an HLA simulation this mean that we can create a base class that contain the common data and extension classes that contain the specific data. A federate can then choose on which level it shall subscribe to TDL messages, enabling e.g a simple CGF to get a situation picture from either a Link 16 Air Track and an ADS-B message depending on the capabilities of the simulator.

The table below list some of the parameters used in ADS-B and Link16, and what data they have in common.

Generic link	**ADS-B (message type 3+4)**	**Link 16 (J3.2 Air Track)**
Latitude, Longitude		
Altitude		
Speed		
Course		
Callsign		
	Vertical rate	
	Is on ground	
	Aircraft id	
		Source track number
		Track quality
		Transponder codes
		Air platform
		Air activity
		Air specific type

Table 2: Track position TDL messages

An example of how an HLA Evolved FOM module for the messages above can look like:

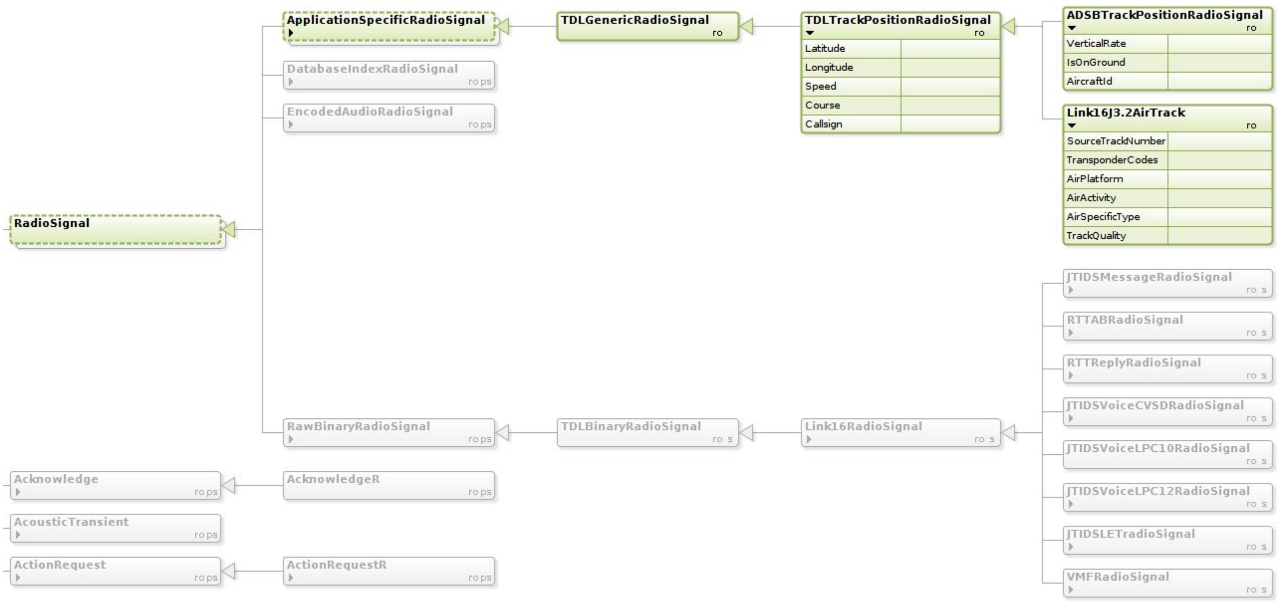

Figure 1: FOM module for own position TDL message

Note that Link16RadioSignal interaction from SISO-STD-002 can be sent in parallel with the TDLGenericRadioSignal interaction if desired to provide data to both Link 16 aware and non Link 16 aware simulators. Both interactions has a reference to a RadioTransmitter object. Since HLA allow for subscription of selected attributes, and Link 16 aware simulator can subscribe to the whole RadioTransmitter object, while a generic TDL aware simulator can subscribe to a subset of the attributes.

5.2. Limitations

Since the generic TDL message will be a simplification of the real link messages, some generalizations must be done. Different TDL:s have different ways of encoding e.g position in latitude and longitude. It might be as a multiple of decimal degrees or as decimal degrees. To make the generic link work with all types of TDL:s a data such as position must be encoded precise enough to support all types of position encodings. The same goes for speed and altitude. Although one link might publish altitude in multiples of 25 feet, the internal representation shall be in decimal meters.
Since the generic link is aimed at simulators that do not have a full e.g Link 16 implementation, several seldom used messages can be excluded from the FOM module. Advanced features such as voice radio and relative navigation may be excluded.

6. Real World Examples

The following chapter discusses two real world examples where there is a need for a standardized generic link simulation module. Both are simulator facilities that provide training and evaluation to the swedish air force.

6.1. Saab Gripen mission trainer 39

The Mission Trainer for the Gripen fighter aircraft (MT39) is a manned mission trainer that is equipped with Link 16 training capabilities. One of the simulators is located at Swedish MOD Test and Evaluation Center (FMV T&E) at Malmen airbase. The purpose of the simulator is to test new editions of the simulator software and other support systems before delivery to the Swedish Air force. It is also used to test integrations that may be used by the Swedish Air force. The simulator consist of the manned cockpit and a CGF. For link simulation between the manned cockpit and the CGF a simple link model that extend the RPR-FOM v2 ApplicationSpecificRadioSignal interaction with a proprietary binary format is used.

There is an ongoing study with the objective to include the MT39 in a LVC simulation, connecting live Gripen fighters, the MT39 manned cockpit and a CGF tool together with live Link 16 C2 network and live ADS-B civilian traffic.
Since the MT39 use it's own link protocol there is a need for specialized gateway that convert from SIMPLE and ADS-B to the MT39 protocol. This gateway will be specific for the MT39 environment. With the existence of a generic link module it would open up for using a COTS gateway and also allow connection of other third party CGF:s and tools.

Summary of link protocols used in the simulator:

Component	**Link protocol**
Live Gripen	Link 16 / SIMPLE through TactX
C2	Link 16 / SIMPLE through TactX
MT39 Cockpit	RPR-FOM v2 ApplicationSpecificRadioSignal
MT39 CGF	RPR-FOM v2 ApplicationSpecificRadioSignal
ADS-B	Mode S / Basestation
TactX CGF	SIMPLE

Table 3: Summary of TDL protocols used in MT39

Swedish Air Force Combat Simulation Centre, FOI FLSC

The Swedish Defence Research Agency (FOI) operates a simulation facility specialized in tactical "many to many" pilot training. The facility consists of several manned cockpits and supporting CGF:s, C2 stations and instructor stations. There is also a complete after action review (AAR) capability. The simulators are built around the modular RPR2 FOM with extension modules for extended functionality. One of the modules is a link module that is modeled on the content of the Link 16 J-messages. This module fulfills the requirement for operation within the facility, but is not sufficient when integrating third party tools that shall participate in the link simulation. A generic link module would open up for easier standardized integration of third party tools. FLSC has a long experience in integration of simulation tools. An example of such an integration is described in reference [13].

7. Discussion

One advantage of a generic TDL FOM is that it will allow simulator developers to build systems with much broader usage. This will in turn allow for more reuse of simulator components and integration of third party products in TDL environments. By not using classified or proprietary data formats interoperability in multinational or civil-military exercises will be simplified.

More specialized TDL simulations using protocols such as SIMPLE has an advantage when all systems already support the specific TDL or when advanced features not supported by a generic TDL is needed.
The existence of a generic FOM together with SIMPLE will make it possible to create COTS bridging software for integration of a wide range of simulation tools in already existing SIMPLE environments.

8. Conclusion

The use of a more generic way of distributing TDL data between simulation participants is required and in use by many simulation applications today. The lack of a standardized way of implementing them has led to many proprietary solutions that are not easily interoperable with other similar implementations and real data links. The addition of a generic TDL FOM module would allow for simpler and standardized representation of a wide variety of data links that would support interoperability with third party simulators and allow for COTS tools to be developed with a plug-and-play TDL capability. The basis for the generic TDL representation should be based on the Link 16 and the J-series of messages since it captures most of the characteristics of other data-link implementations and is the most common data link that is represented in today's simulators.

The addition of better support for TDL and other data-links in the RPR-FOM would make the RPR-FOM more complete and enable it to better support the requirements of a modern battle space environment and also support a wider simulation community. For the simulation community in general, a more generic support for Data Links may also provide a number of reusable patterns for other areas such as CBML.
The HLA standard provide a clear separation of the semantics and the transport protocol, and is therefore suitable for modeling a generic TDL. Similar TDL support can also be added to the DIS standard for backward compatibility, but the lack of separation between semantics and transport protocol will make it a bit more involved.

9. References

[1] IEEE: “IEEE Std 1516™-2010, IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)—Framework and Rules”, 2010

[2] SISO: “SISO-STD-001.1-2015, Standard for Real-time Platform Reference Federation Object Model”, 2015

[3] Northrop Grumman: “Understanding voice and data link networking - Northrop Grumman’s guide to secure tactical data links”, 2014

[4] Wikipedia: “https://en.wikipedia.org/wiki/Automatic_dependent_surveillance_%E2%80%93_broadcast”, 2016-06-27

[5] Wikipedia: “https://en.wikipedia.org/wiki/Automatic_Identification_System”, 2016-06-27

[6] “STANAG 5516, Tactical Data Exchange - Link 16”

[7] “MIL-STD-6016, Tactical Data Link (TDL) 16 Message Standard”

[8] “Tactical Data Link (TDL) 11/11B Message Standard”

[9] Basestation format: “http://woodair.net/sbs/Article/Barebones42_Socket_Data.htm”, 2016-06-27

[10] SISO: “SISO-STD-002-2006, Standard for Link 16 Simulations”, 2006

[11] IEEE: “IEEE Std 1278.1™-2012, IEEE Standard for Distributed Interactive Simulation—Application Protocols”, 2012

[12] “STANAG 5602, Standard Interface for Multiple Platform Link Evaluation (SIMPLE)”

[13] Möller B, et .al: “05F-SIW-118, Gaming and HLA 1516 Interoperability within the Swedish Defense”, 2015

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