MILCAN

Adapting COTS CANbus to Military Vetronics

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The success of CANbus in commercial automotive applications effectively guarantees long-term availability and support. The fact that CAN is inherently rugged makes it an attractive proposition for military vehicle (vetronics) applications.

In practice though, vetronics applications are characterized by the need for absolute interoperability. More than just electrical or data transfer protocols, this encompasses a worldwide "plug and play" mentality across multiple vendors, vehicles, and subsystem functions. In addition, specific operational requirements may include the field reconfiguration of subsystems in order to preserve critical vehicle functionality and safety.

This paper details the history and implementation of MILCAN, a protocol developed under the auspices of the International High Speed Data Bus User's Group in order to address the whole range of military vetronics requirements. Specific protocol issues covered include the benefits of a functionally partitioned architecture, frame formats, determinism, and message latency. MILCAN is derived from other CAN protocols such as the CUP protocol developed byt he German BWB, ISO 11898, SAE J1939, and CANopen.

Introduction

The success of CANbus in commercial automotive applications effectively guarantees long-term availability and support. The fact that CAN is inherently rugged makes it an attractive proposition for military vehicles.

In practice, though, military and commercial vehicles differ substantially in their operational requirements. Data determinism, safety criticality, and failure modes along with subsequent error recovery are all key factors. There are other, significant system differences between military and commercial vehicles that must be considered. For example, an individual military vehicle may need to be upgraded many times during a service life of 25 years or more, while new features are generally not added to in-service commercial vehicles. Interoperability between components manufactured by different subsystem and test equipment manufacturers is vital for military vehicles.

To this end, the MILCAN interface is intended to provide an interconnect specification that can be used by system and equipment developers to enhance the interoperability of their products.

MILCAN is intended to be easily bridgeable to other CAN-based protocols, specifically SAE J1939 and CANopen. It should be possible to mix J1939 devices with MILCAN devices on the same bus. CANopen devices must be segmented via a bridge, but the intention is that MILCAN define a specification that includes CANopen device profiles using the same MILCAN messages.

MILCAN development

At the February 1998 meeting of the International High Speed Data Bus Users Group (IHSDB-UG, which is sponsored by NATO) a CANbus working group was formed because existing CAN protocols did not provide the hard real-time capabilities required in a military environment, and were not truly open and in the public domain. This working group has met approximately every 3 months since its inception, with the goal of creating an open standard interface tot he CAN databus technology that supports implementation in all military vehicle application areas where the performance requirements are commensurate with that of the CANbus.

The group recognized the strengths of existing protocols, and made a conscious effort to build upon them wherever possible. As a result, MILCAN makes reference to ISO 11898 to a great extent. Other protocols that form the basis for MILCAN are J1939, and the CUP protocol developed by the German BWB.

MILCAN organization

At this stage, MILCAN can only be an advisory document, beginning the process of guiding the military equipment community in the same direction. MILCAN is actually implemented in 3 documents. The Physical Layer defines electrical connectivity, transceiver characteristics, and bit timing. The Data Link Layer defines framing, bus access control, and message types. The Application Layer defines the wider communication architecture, identifier assignment, and deterministic message transmission.

Each MILCAN document defines the mandatory features required for interoperability. Within this framework there are cases where a number of options may be possible without sacrificing interoperability. In these instances, a set of recommended practices is suggested. A good example of this is the chassis level I/O connector selected. With appropriate cabling, any suitable connector could be utilized, but by recommending a default connector and pin-out, MILCAN introduces a degree of stability.

In addition, MILCAN recognizes the existence of fielded CAN nodes and differentiates between features which are mandatory from day one, and those which must eventually be included prior to achieving full compliance For example, baud rates must always be consistent, but bus termination can be implemented in several ways.

Physical Layer

MILCAN recommends that CAN signals are opto-isolated and that these be driven from an isolated supply. The wide range of both transient and steady state voltage levels that must be tolerated within a military vehicle mean that power supplies are often both complex and expensive. MILCAN recognizes this system-wide cost issue, and goes beyond ISO 11898 in supporting the concept of an in-cable power supply in order to efficiently provide power to remote node transceivers from a central supply. This potential to carry power means that although the MILCAN physical layer simply recommends a connector type, gender assignment becomes very important. Thus, regardless of the network topology, any connector that may constitute a power source must be female.

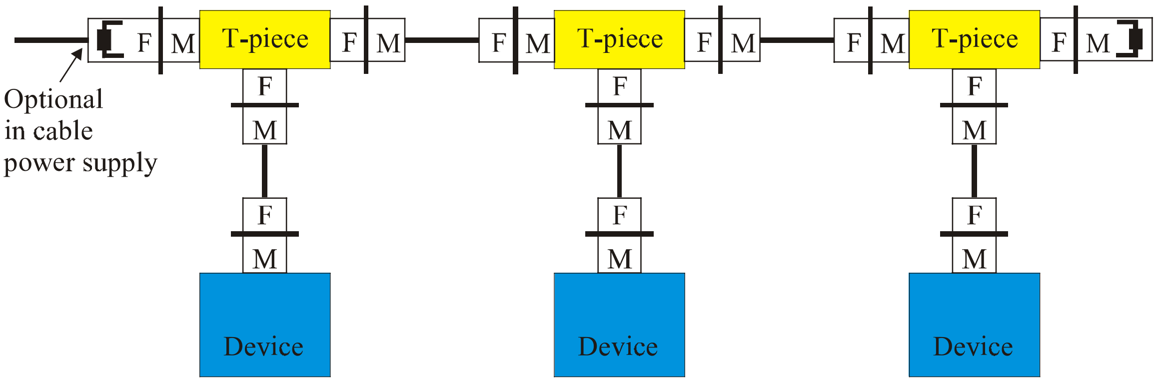

Figure 1.1 MILCAN Linear topology

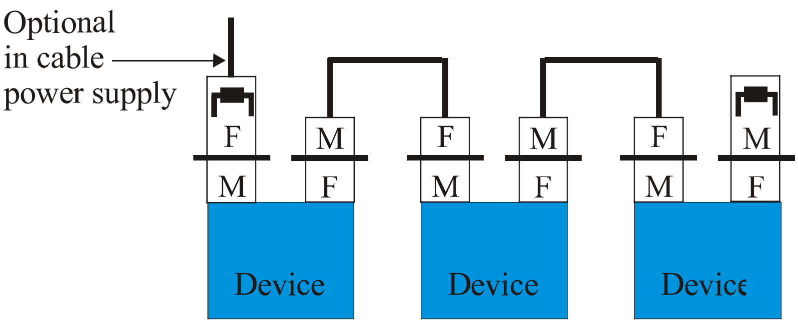

Figure 1.2 MILCAN daisy chain topology

The figures above provide examples of the two basic network topologies. Figure 1.1 illustrates the linear topology, while Figure 1.2 shows a daisy-chain configuration. The figures also demonstrate the recommended termination resistor placement. Placing the resistor in the connector rather than in the network device itself creates a mechanism whereby all nodes can remain fundamentally the same, which is important for the COTS concept of single interchangeable Line Replaceable Units. In addition the fact that upgrades will by default require new cabling helps to avoid the inadvertent duplication of termination networks.

Data Link Layer

MILCAN uses only the 29 bit, extended, identifier format defined in ISO 11898. This format is based upon SAE J1939 in order to allow both formats to be used on the same bus differentiated by the Protocol type bit, bit 25.

As with any CANbus implementation, data is broadcast, and bits 0 to 7 of the identifier include the physical address of the device that actually transmits a frame, rather than a destination address. This enables multiple remote nodes to determine where a message originated and distinguish between similar messages from different devices. The MILCAN Data Link Layer also defines message type and a priority level using bits 26-28 of the frame identifier in order to allow the application layer the ability to allocate priorities on a message specific basis as part of a latency guarantee within the deterministic message transmission protocol.

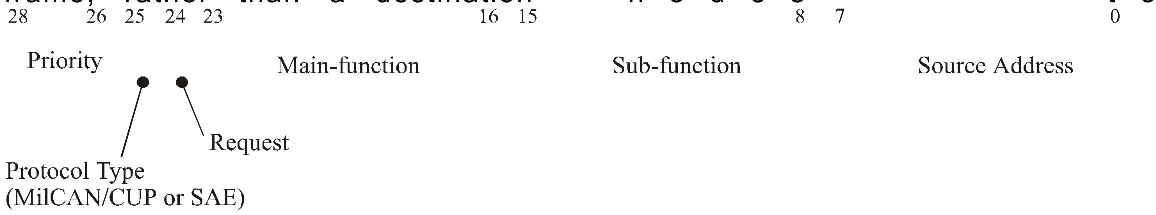

Figure 2 MILCAN Frame identifier format

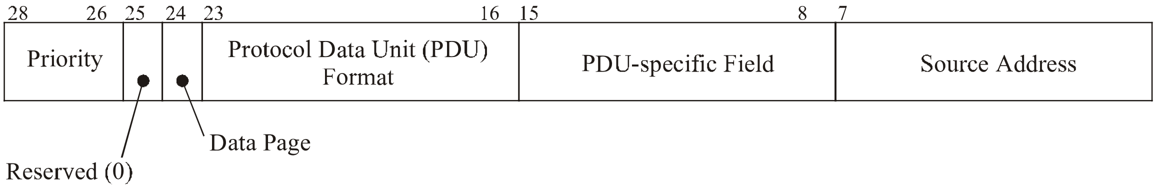

Figure 3 J939 Frame identifier format

Multi-frame messages

If a message's data payload exceeds eight bytes then it will have to be distributed across more than one CAN data frame which, depending upon the nature of the data, can be handled in one of two ways. In order to guarantee delivery performance, time-critical or safety-critical data will normally be transmitted as a group of single frame messages each with unique function identifiers. If, however, the data is not critical, then it can be transmitted by means of a number of linked data frames. This is termed a multi-frame message. A dedicated handler is required in order to manage individual frames within a multi-frame message and issue them to the data link layer. The mechanism makes use of the normal frame format but uses the first data byte of the payload to pass a code used to guarantee the chronology of the data. At the start of a multi-frame message this is set to 0, incrementing up to 249 with each succeeding frame. At 249 the leading data byte value rolls over to 1. A value of 250 is reserved to indicate the end of a multi-frame message regardless of the number of individual frames. Because of this encoding scheme a maximum, of seven data bytes can be transmitted per frame.

MILCAN does not require frame acknowledgement. That determination is left up to the message's application layer specification. The frame counter is restricted to the range 0 to 250 in order to maintain the convention established in SAEJ1939 whereby values above 250 are reserved for special purposes.

Application Layer

The MILCAN application layer adopts a segmented message assignment scheme and flexible deterministic protocol in order to accommodate both vehicle and application dependent changes.

Message identifier assignment

The MILCAN 29-bit identifier is illustrated in Figure 2. Bits 28-26 define the priority of an individual message and therefore the priority of the associated data frame. Bits 23-16 define the 256 message primary types and bits 15-8 the 256 message sub-types for each primary type.

Message primary type identifiers are assigned sequentially starting at zero and with a spare identifier between each assignment. Sub identifiers are also assigned sequentially starting at zero with a spare identifier in between each. Messages are grouped by means of their primary types e.g. Navigation, Power Management, MMI devices, Data acquisition etc.
This structured approach to identifier assignment offers a number of distinct benefits:

- It is relatively simple to implement course filtering using only the primary type octet or fine filtering using the combined primary and sub-type octets.

- Backward compatibility is maintained. New message types can stem from previous types (class based inheritance) and so be identifiable as sub-types of the existing message, e.g. “Threat detection” may be split into “UV flare threat detection” and “Doppler radar threat detection”.

- Completely new message types are relatively easy to add to the message dictionary and are added in an efficient manner serving both future upgrade scenarios and new application areas equally well.

Should it become apparent that one primary message type requires many sub-types while a neighboring primary message type requires only a few, then by simply moving that primary/sub boundary to bits14/15 will increase availability by 50% without compromising backward compatibility.

Multi-instance addressing

Efficient message allocation is vital, but it is important to recognize that when the initial allocation is made, the number of physical instances of that function can not be predicted. For example, consider a message designed to control a particular camera function. At the outset it is not known how many cameras will need to be supported, and indeed the number and location may vary from vehicle to vehicle. To support this requirement MILCAN defines a multi-instance addressing scheme that is independent of message type.

If applicable to a particular system function message, then the MILCAN physical instance element is carried within one byte of the data payload rather than the source address field.

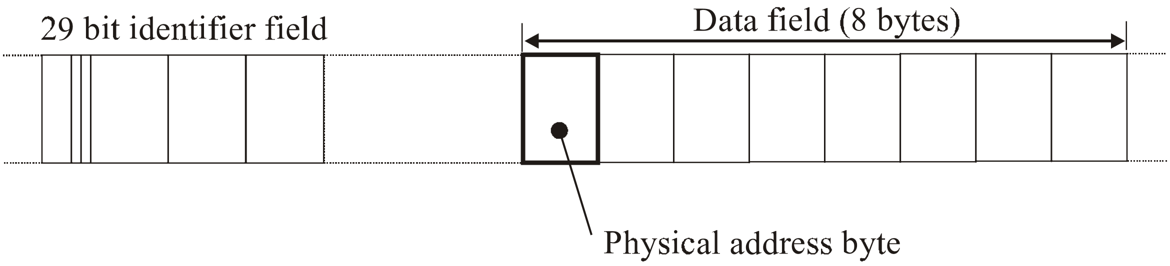

Figure 4 MILCAN Multi-instance frame

This protocol has two distinct advantages:

- The source address relates to a CAN node and should not be linked in any way to the system functions that are using this node to access the bus. By placing the physical instance element in the data payload, functions can be moved either statically or dynamically from one node to another.
- The number of physical elements on a node can vary and this scheme allows node to distinguish between them. A single source address would not.

Support for deterministic message transmission

In a military environment, there are many cases where data must be transmitted between nodes with precise and repeatable timing. A servo control loop is a good example. MILCAN provides a network data flow structure to accommodate such real-time needs without requiring non-time-critical devices to incur the overhead of complicated time-slice transmission. Devices connected to a MILCAN network will vary greatly in their capabilities, hence support for deterministic message transmission must be provided by both sophisticated and simple devices.

MILCAN uses a prioritized bus access with bounded throughput protocol. This supports determinism for those devices that require it while providing sufficient flexibility for those devices that do not.
Put simply, a number of time unit levels are defined; each has a particular latency guarantee and individual nodes are only allowed to transmit one message within their allocated period..

Assuming the largest possible data field (8 bytes) the CAN protocol guarantees the delivery of 15 messages within each Primary Time Unit (PTU). In an extreme case this could equate to 15 Level 1 messages. In practice each PTU is more likely to support some level 1 messages with the remainder of the 15 slots being spare or made up of a combination lower priority Level 2, Level 3 or Level 4 messages. This is illustrated in Figure 6. In the figure, HRT stands for Hard Real Time, or message where timing and latency are very critical to system performance. SRT indicates Soft Real Time messages, where timing is still important, but absolute latency is not critical.

Priority (bits 28-26)	Message Transfer Performance Criteria
0 (highest)	Protocol Operation Messages (e.g.SYNC) and low jitter messages
1	HRT1 – Level 1, latency guarantee-within a PTU (2ms@1Mbit/s)
2	HRT2 – Level 2, latency guarantee 8 PTUs (16ms@1Mbit/s)
3	HRT3 – Level 3, latency guarantee 64 PTUs (128ms@1Mbit/s)
4	SRT1 – Level 2, latency guarantee 8 PTUs (16ms@1Mbit/s)
5	SRT2 – Level 3, latency guarantee 64 PTUs (128ms@1Mbit/s)
6	SRT3 – Level 4, latency guarantee 512 PTUs (1024ms@1Mbit/s)
7 (lowest)	Non Real Time (NRT), use any available space

Table 1 Message priority assignment

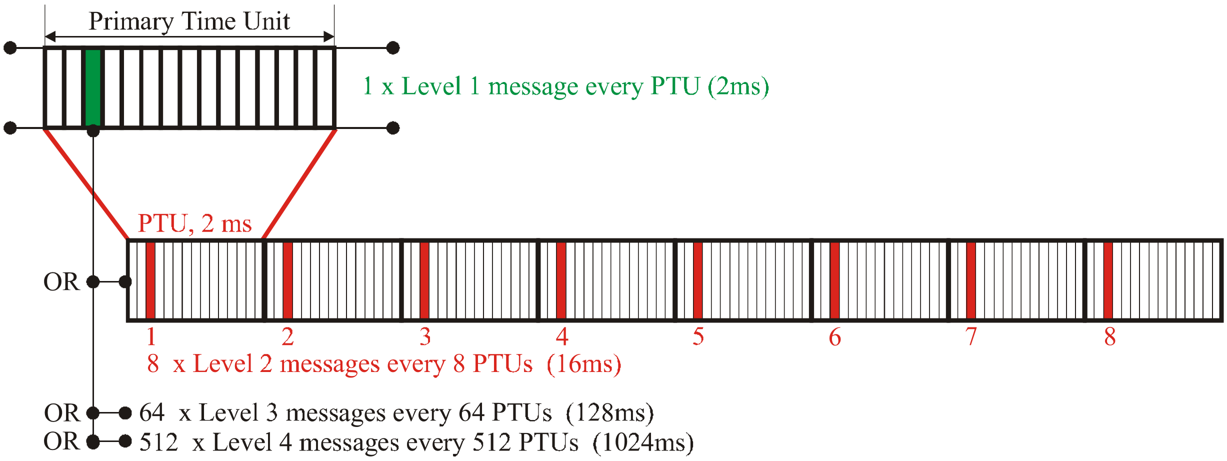

Figure 5 Message Delivery

This bus allocation method achieves a number of goals:

- Support for HRT, SRT and NRT messages.
- Support for both event driven and periodic messages.
- Limitation of the maximum trigger rate of each message to no more than one message per unit time in order to provide bus capacity for low priority messages.
- Support for the inclusion of a “sync” message once per unit time for those nodes which require it.
- Support for fault recovery, jitter and other errors in message trigger timing.

Support for synchronization between devices

Military vetronic architectures are normally comprised of multiple distributed real-time sub-systems, and as a result the communication protocol employed must support both determinism and co-ordination. The MILCAN protocol defines a “sync generator claim message” and its use as part of an arbitration process in order to elect a network sync generator. It is this sync generator which broadcasts a “sync frame” every PTU in order to provide a means by which nodes can co-ordinate actions.

Resilience is prerequisite to any military communications architecture, and as a result, any node which requires use of synchronization frames must also monitor the bus for their absence. If a node detects that the sync message is late, either due to a sync generator failure or because the network has just powered up, then that node must trigger the claim process in order to elect a new sync generator. Once triggered the arbitrated claim process only requires two frames to be transmitted, the first is the winning transmission and the second signals loosing nodes to cancel their claim process. The new sync generator immediately begins transmitting sync frames.

Current status

At this stage MILCAN can only be considered as advisory documents, beginning the process of guiding the military equipment community in the same direction. In themselves the existing documents do however provide a basis for implementation and the intention is to translate these into an open standard suitable for ratification within the next twelve months.

As an adjunct to the standardization process, mechanisms will also be put in place to support the long-term maintenance of the standard. By doing this, it will it be possible to ensure a coherent message definition policy spanning the diverse requirements of military land, sea and air applications.

Conclusions

MILCAN has achieved its primary goal in that it provides a sound basis for CANbus interoperability across the full range of military vehicle platforms. And this has been achieved without sacrificing compatibility with existing protocols used in the military arena since MILCAN supports the transport of pre-existing frame structures.

The requirement to implement a fully deterministic protocol has necessitated some departure from existing protocol conventions though. MILCAN maintains a balance by supporting the concept of bridges to bus segments that utilize alternative protocols.

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