

March 2016

# *Controller Area Network*

*The network for mobile working machines*

*future  
proofed*



*With improved features ready for  
the Internet of Things (IoT)*

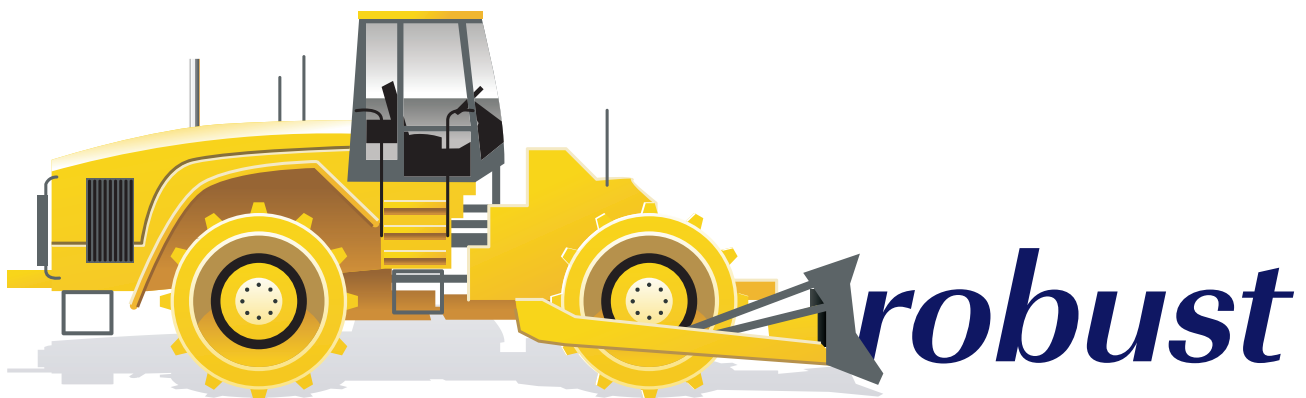
*具备适配物联网 (IoT)  
改进功能的*

Modern construction and mining machines are stuffed with electronics. The used electronic control units need to be connected to each other as well as to sensors and to actuators (e.g. hydraulics and electrical drives). Of course, there are also human machine interfaces to be linked to the electronic control system. Controller Area Network (CAN) is the most chosen communication technology, y of its robustness and reliability.

CAN, internationally standardized in the ISO 11898-1 series, is proofed in millions of passenger cars and many other safety- and mission-critical applications. The CAN transceiver and protocol controller chips are available for very reasonable prices from different manufacturers. CAN is a mainstream communication technology with more than 1,5 billion of nodes installed annually.

现代工程机械和采矿机械配备了各种电子设备。被使用的的电子控制单元不仅需要彼此互联,也要和传感器和传动装置(如液压和电气驱动),以及人机界面进行互联。控制器局域网(CAN)以其鲁棒性和可靠性成为最多被选择的通讯技术。

CAN作为国际标准化串行网络(ISO 11898-1)已经经过数以百万计的客车以及其他对安全性和任务有严格要求的应用的检验。CAN收发器和协议控制器芯片可从不同的生产商处以合理的价格购买。CAN作为主流通讯技术,每年有超过15亿的节点安装。



Classical CAN is used in construction and mining machines for more than 20 years. In many cases, the machine builders use transmission rates of 250 kbit/s. This allows a robust communication in networks with a length of up to 250 m. The maximum payload in a single message is limited to 8 byte by the Classical CAN protocol already introduced in 1986.

传统的CAN已在建筑和采矿机械中已使用了超过二十年。在多数情况下,机械制造商使用250 kbit/s的数据传输率。这允许了可达到250米的稳健的通讯网络。按照1986年提出的传统CAN协议,单个报文的最大有效载荷限为8字节。

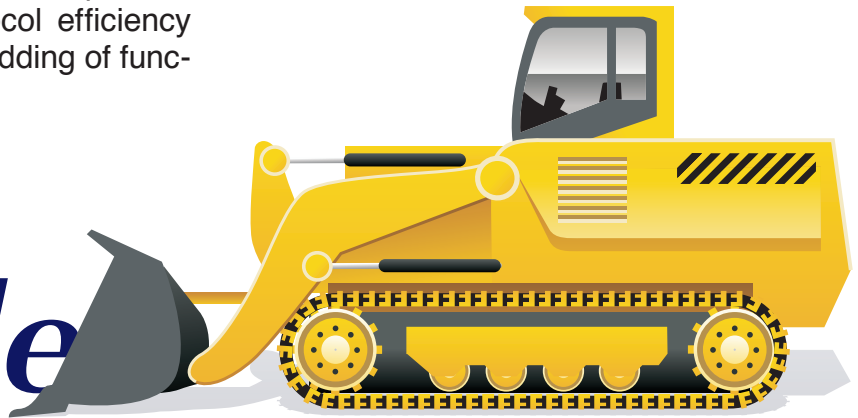
In order to overcome the bit-rate limitation at a given network length and the 8-byte payload limit, the CAN community has improved the ISO 11898 data link layer and the physical layer standards in the last few years. These improvements, resulting in the CAN FD (flexible data rate) protocol, are already standardized in ISO 11898-1:2015 respectively ISO 11898-2:2016.

CAN FD frames are transmitted with two data-rates: the arbitration bit-rate as known from Classical CAN and the data-phase bit-rate, when just one node is actively transmitting. Using a 250-kbit/s arbitration bit-rate with a 2-Mbit/s data-phase bit-rate enables a significant data throughput increase. Theoretically, even higher data-phase bit-rates are possible. The ISO 11898-2:2016 specifies transceiver chips supporting 5 Mbit/s. In addition, the CAN FD protocol allows payloads up to 64 byte. This improves the protocol efficiency dramatically and enables the adding of functional safety and security data.

为了克服在给定网络长度和8字节数据载荷限定下的比特率限制,在过去的几年中, CAN联盟一直致力于ISO11898数据链路层的改进和物理层的标准化。改进的结果: CAN FD (灵活的数据传输率)协议已分别通过ISO 11898-1:2015 和 ISO 11898-2:2016 标准化。

CAN FD帧可以通过两个数据率传送: 与传统CAN相同的仲裁比特率和在只有一个节点主动传输时的数据阶段比特率。使用250kbit/s的仲裁比特率和2 Mbit/s的数据阶段比特率可以使数据吞吐量有显著的提高。理论上,更高的数据阶段比特率也是可行的。ISO 11898-2:2016指定收发器芯片支持5Mbit/s。此外, CAN FD协议允许有效载荷可达64字节。这将显著提高协议的效率, 并实现功能安全和保密数据的添加。

*reliable*



The Classical CAN and the CAN FD protocols are simple and can be adapted to many applications due to their flexibility. CAN FD controllers also support the Classical CAN protocol. The reliability of these protocols is very high: Any single bit-error is detected. Multiple bit-errors are detected with a high probability due to the protocol inherent error detection mechanisms. This includes sophisticated CRC (cyclic redundancy check) polynomials. Any detected error causes an automatic retransmission of the faulty message. The protocol controllers do this error handling automatically. The user is unburdened from this task. This is one reason, why CAN is so easy to use.

传统CAN协议和CAN FD协议都很简单,并且由于其灵活性适用于很多应用。CAN FD控制器也支持传统CAN协议。这些协议的可靠性都非常高,可以检测到所有单独的位错误。协议固有的错误检测机制决定了可检测到多个位错误的高概率,这包括了精细的CRC (循环冗余校验)多项式。若有任何错误被检测到,有错误的报文就会被自动重新传输,协议控制器将对该错误进行自动处理,减轻用户负担。这也是为何CAN可如此简单使用的原因之一。

In order to simplify system integration of devices from different manufactures, standardized higher-layer protocols are needed. In construction and mining machines, CANopen and SAE J1939 are the most common. The days of proprietary solutions are gone. The standardized use of CAN is on the agenda.

CANopen is the internationally standardized (EN 50325-4) application layer for embedded networks developed by members of the nonprofit CiA (CAN in Automation) association. It specifies the communication services and protocols for configuration, real-time control, and diagnostic. CANopen is a very flexible approach: It pre-defines the communication and provides nevertheless configuration options. It uses by default the Base Frame format with 11-bit identifiers, and supports optionally the Extended Frame format with 29-bit CAN-IDs. CANopen FD is under development making use of the improved features of CAN FD.

For applications requiring functional safety, the CANopen Safety protocol (EN 50325-5), applicable up to the Safety Integrity Level (SIL) 3, can be used. Several CANopen host controllers and sensors support this protocol extension and are already certified by appropriate authorities such as the German TÜVs.

The SAE J1939 higher-layer protocol is widely accepted by the diesel engine manufacturers. It uses the Extended Frame format of the Classical CAN protocol. In agriculture and forestry machines, a J1939-derivat, the Isobus (ISO 11783 series) is internationally standardized for tractor-to-implement communication. Implements include add-on-devices such as sprayers and harvesting machines.

CiA develops a solution, which maps J1939 messages to CAN FD frames. The CiA 602-2 specification uses a multiple PDU (protocol data unit) concept, which complies with Autosar, a bus-independent software layer and middleware.

为了简便不同生产商的设备系统集成, 需要标准化的高层协议。在工程机械和采矿机械中, CANopen和SAE J1939最为常用。专有解决方案的日子已经一去不复返了, CAN标准化的使用已经提上日程。

CANopen是国际标准化(EN 50325-4)应用层, 可用于嵌入式网络。是由非盈利性组织CiA (CAN in Automation)的会员联合开发的。规定了适用于配置、实时控制和诊断的通讯服务和协议。CANopen是一种非常灵活的方法: 它预先定义通讯, 并提供充分的配置选项。它默认使用带11位标识符的基础帧格式, 并可有选择性地支持扩充帧格式(29位标识符)。正在研发中的CANopen FD可利用CAN FD的改进功能。

对于需要安全相关的通讯的应用, 可使用CANopen 安全协议(EN 50325-5), 该协议适用于要求达到安全完整性等级(SIL) 3的应用。许多CANopen主控制器和传感器支持该协议扩展, 并已经通过有关当局(如德国TÜV)认证。

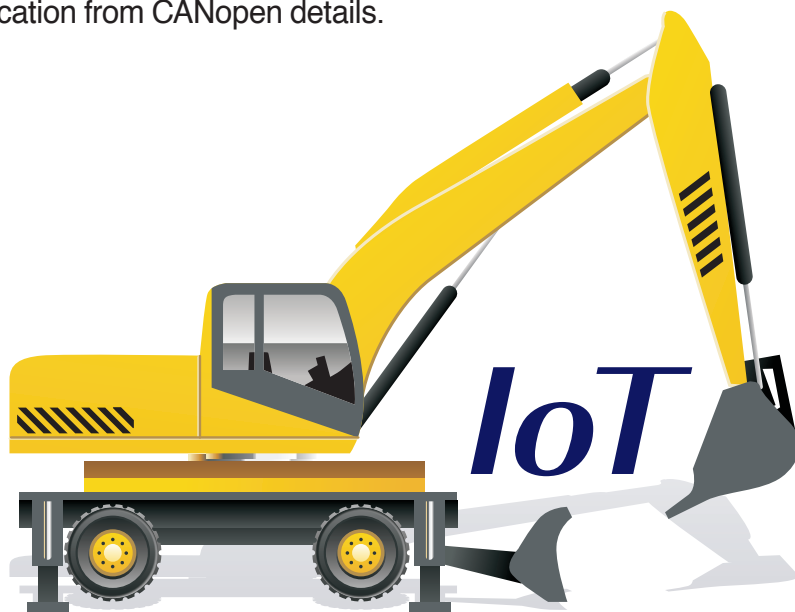


SAE J1939 协议得到柴油发动机制造商的广泛支持。该协议使用传统CAN协议的拓展帧格式。在农林机械方面, 作为J1939的衍生协议, Isobus (ISO 11783)是拖拉机与其他机械互联互通(包括了如喷雾机具的附加设备和收割机)的国际标准。

CiA开发了将J1939消息映射到CAN FD帧的解决方案: CiA602-2规范使用了一个多PDU(协议数据单元)的概念, 符合Autosar(总线独立的软件层和中介软件)。

State-of-the-art fleet management systems as well as remote diagnostics systems demand a simple access to CANopen-based in-vehicle networks via Web services. The mobile machine should be a thing in the Internet. To meet this requirement, the CiA association develops an appropriate Internet-of-Things (IoT) to CANopen gateway. This requires a functional addressing instead of network-ID and node-ID. Therefore, new attributes are introduced in the Electronic Datasheet (EDS), the electronic representation of a CANopen device. The functional addressing frees the IoT application from CANopen details.

现代化的车队管理系统以及远程诊断系统需要一个简单的访问通路，用于通过Web服务来访问基于CANopen总线的车载系统。车辆应该成为互联网中的一部分。为了达到这个构想，CiA协会开发了适用于物联网(IoT)转CANopen网关。IoT需要一个功能性寻址，来取代网络ID和节点ID。因此在电子数据表(EDS)中介绍了新的属性：CANopen设备的电子表示。功能性寻址功能将物联网应用从CANopen的细节中解放出来。



As soon as the CANopen network is known by the IoT gateway, it can use generic communication services as specified in the CiA 309-1 specification. They are mapped to a URI (uniform resource identifier) schema and to an XML (extended mark-up language) schema. CANopen FD will support this approach by means of inherent routing-capable USDO (universal service data object) services. The USDO protocols replace the SDO protocols of CANopen. They also provide data segmentation services in order to transmit user data larger than 64 byte. Additionally, it is planned to provide USDO communication in broad- and multicast. The legacy SDO protocol allows just unicast communication between one SDO client and one SDO server.

The longer payload of up to 64 byte allows adding security information for authentication or data encryption. This is necessary to protect the in-vehicle network against unauthorized access.

只要物联网网关识别到CANopen网络，它就可以使用CiA309-1规范的通用通讯服务。它们被映射至URI (唯一接收标识符) 模式以及XML (可扩展标记语言) 模式。CANopen FD将会通过内部可路由的USDO服务 (普遍服务数据对象) 来支持这种访问途径。USDO协议替换了CANopen中的SDO协议。它们也提供了数据段服务，以便传输多于64位的用户数据。此外，以全体广播及多路广播来提供USDO通讯服务也已在计划中。之前的SDO协议只允许在SDO用户和SDO服务器之间单一广播的通讯方式。

长度可最多至64位的有效数据载荷允许增加权限验证以及数据加密方面的安全信息。此项措施在保护车载网络抵抗未授权的访问中是必需的。

Higher-layer protocols provide a standardized access to devices via the CAN network. However, they do not specify the process data (commanded values and current values), the configuration parameter, and the diagnostic information. This is done in so-called profile specifications. They are necessary for the interoperability of devices.

Therefore, CiA has developed several device and application profiles for CANopen. In construction and mining machines, highly interoperable encoders (CiA 406), inclinometers (CiA 410), and hydraulic devices (CiA 408) are implemented. Additionally, generic I/O modules including joysticks and keypads (CiA 401) are often used. There are available also special CANopen profiles: CiA 415 for sensors in road construction machines, CiA 444 for container spreaders, CiA 455 for drilling machines.

高层协议通过CAN网络提供了一个标准化的至设备的通道。然而，过程数据（要求值和即时值），配置参数，诊断信息没有被规范化。这个就是所谓的子协议规范。子协议规范对于设备的可互操作性是必要的。

因此，CiA已经开发了多个关于CANopen的设备子协议和应用子协议。在建筑和采矿机械方面，高可互操作性的编码器（CiA 406），倾角倾斜仪（CiA 410），和液压装置（CiA 408）已经被实现。此外，通用I/O模块，包含控制杆和按键（CiA 401）也经常使用。一些其他可用的特殊CANopen协议也已编写完成：用于道路建设机械传感器的CiA 415，用于集装箱吊卸梁的CiA444以及用于钻孔机的CiA 455。

## *interoperable*



Additionally, CiA has standardized the CANopen gateway to J1939-based networks in the CiA 413 series. The SAE J1939-71 specification describes the data content of the so-called Parameter Groups. These are 8-byte CAN messages, which maps one or multiple process data. They are not configurable as the PDOs (process data objects) in CANopen.

同时，CiA已经在CiA413系列中标准化了对于基于J1939网络的CANopen网关。SAE J1939-71规范描述了所谓参数组的数据内容。数据内容是由8位的CAN报文组成，他们可以映射至一个或多个过程数据。他们和CANopen中的PDOs（过程数据对象）不同，是不可配置的。

Some construction and mining machines require an open communication system. This is an off-the-shelf plug-and-play approach. The end-user is so-to-say the system designer, who normally has no deep knowledge on CAN communication. In CANopen this pre-requisites the use of the Layer Setting Services (LSS) as specified in CiA 305. The CANopen host controller uses these services to assign uniquely node-IDs to the CANopen devices and set optionally the bit-rates.



Besides such user-programmed and user-configured off-the-shelf plug-and-play solutions, CiA members may develop standardized CANopen application profiles within Special Interest Groups (SIG). If at least three parties request such a profile, CiA Headquarters organizes an inaugural meeting to agree on the scope of the desired profile. CiA's technical staff supports the profile development as well as the specification editing.

Application profiles depend on the demands of CiA members, who also comment the proposed specifications and finally vote on them. In order to make the profiles as good as possible, the expertise of the machine building industry (OEMs and suppliers) is needed. CiA invites especially machine builders to participate in the profile development process.

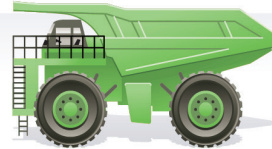
Off-the-shelf plug-and-play networks based on J1939 are also possible, when the automatic address-claiming feature is implemented. Unfortunately, this function implies the risk that nodes transit into bus-off mode.

某些建筑和采矿机械需要使用开放的通讯系统。这是一种现成的即插即用的方案。终端用户,也可以说是系统设计人员,一般并不具备有关CAN通讯协议的深层次知识。在CANopen中, CiA 305规范了使用层设置服务的先决条件。CANopen主机控制器使用此服务来分配唯一的节点ID给CANopen设备,也可选择性的设置比特率。

除了这些用户可编程,用户可配置的现成即插即用方案, CiA成员也可与特殊兴趣小组 (SIG) 共同研发标准化的CANopen应用规范。若对同样规范有研发需求的团体达到三家, CiA总部会组织一个开题会议并在会上就所需要子协议规范的使用范围达成一致。CiA的技术人员会在子协议开发及其技术规范编辑方面提供支持。

应用子协议取决于CiA成员的要求,这些成员对提议的技术规范发表评论,并最终投票决定。为了能使该子协议尽善尽美,需用到设备制造行业(OEM和供应商)的专业知识。CiA特别邀请机械制造商参与到子协议的开发过程中。

当自动寻址功能被执行时,基于J1939的现成即插即用网络也是可用的。可惜此功能存在由节点传输至总线关闭模式的危险性。



The aim of the 1992 established CiA organization is to promote CAN's image and to provide a path for future developments of the CAN technology (e.g. CAN FD). End of 2015, about 600 members and institutes have joined the nonprofit group. CiA provides technical and marketing information for users and manufacturers of CAN-based hardware and software by means of its website, the CAN Newsletter, and a technical hotline by email.

The CiA association offers services for members and non-members including seminars and consulting. In addition, CiA tests CANopen devices on conformity to CiA 301 (application layer) and interoperability (e.g. plugfests).

The main service is the development and maintenance of CiA specifications. CiA Headquarters edits and releases CANopen-related specifications, application notes, and recommended practices. Additionally, the CiA 601 series (CAN FD node and system design recommendations) and the CiA 602 series (Mapping of J1939 to CAN FD) are under development.

CiA国际用户和制造商组织成立于1992年，致力于提升CAN形象以及为CAN技术的持续发展提供一条途径（例如CAN FD）。截至2015年，已有大约600个成员和机构加入到CiA非盈利组织。通过CiA网站，技术杂志 CAN Newsletter 以及技术热线电子邮件，CiA为基于CAN的硬件及软件的用户和制造商提供了技术以及市场方面的信息。

CiA协会可为成员以及非成员提供的服务包括研讨会和咨询服务。同时，CiA 还可对于CANopen设备进行一致性测试：是否符合CiA 301（应用层协议）以及可互操作性（例如plug fests）。

CiA的主要服务为开发和维护CiA规范。CiA总部编辑并发布了CANopen相关子协议规范，应用注意事项以及操作规程建议。此外，CiA 601系列规范（CAN FD 节点和系统设计建议）和CiA 602系列规范（J1939到CAN FD映射）正在持续研发中。

CAN in Automation (CiA) e. V.  
Kontumazgarten 3  
DE-90429 Nuremberg  
Phone: +49-911-928819-0  
Fax: +49-911-928819-79  
headquarters@can-cia.org  
www.can-cia.org