

## Controller Area Network and CANopen in Medical Equipment

a report by

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Controller Area Network (CAN) is an international standardised data link layer protocol (International Organization for Standardization (ISO) 11898-1). Originally developed for use in passenger cars, it is now also used in many other application fields. Since 1992, it has been implemented as an embedded network in different medical equipment.

The CAN protocol specifies only the basic communication services. Every user has to specify a so-called application layer and communication profile that define the use of identifiers, configuration of devices and network management. Also, if the content of the data to be transmitted and received should be standardised, the so-called application objects have to be specified.

In the past, many European manufacturers of medical equipment have developed CAN interfaces based on proprietary protocols. Now, those companies try to migrate to existing standardised CAN-based higher-layer protocols. One of these solutions is CANopen, originally developed by members of the CAN in Automation (CiA) international users' and manufacturers' group, a non-profit organisation. CiA has established a special interest group (medical), which specifies a CANopen device profile for medical devices. The very first CANopen interface profile for medical applications is the CiA Work Draft (WD) 412 profile for collimator subsystems.

### Layered Architecture and Communication Model

Any communication system can be regarded as a layered system (ISO/Open systems Interconnection (OSI) Reference Model). In human communication, the first layer (physical layer) can be compared with a sheet of paper and a typewriter ribbon. In CANs, this functionality is implemented in CAN transceiver chips that are compliant with ISO 11898.

In human communication, the Latin character set can be regarded as data link layer (layer 2) protocol. In CANs, this functionality is represented by the CAN protocol itself. Latin characters may be used to define language, as many early CAN users did.

However, as in human communication, interoperability between devices will not be achieved when implementing different application layers. This is the reason why CiA members have developed the CANopen application layer and communication profile, which is like 'continental English' – a basic version of English grammar.

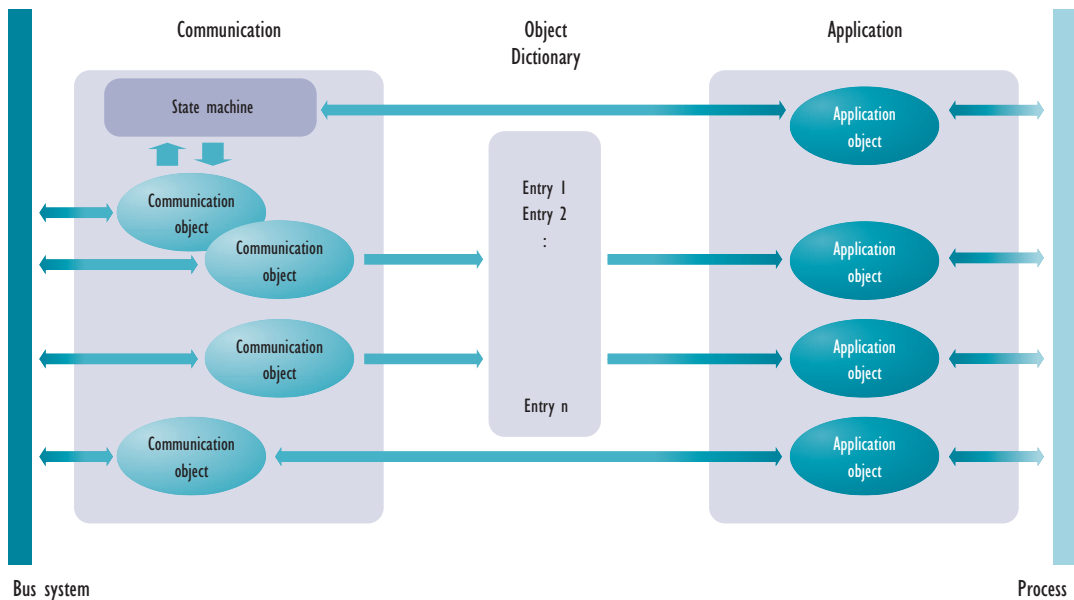
To learn a language takes a lot of effort, which is the reason why, in human communication, there are phrase books available. In CANs, those phrase books are called device, interface and application profiles and they specify the content of the transmitted objects. For CANopen, there are several general-purpose device profiles already available, and CiA will develop additional medical-specific profiles such as for X-ray generators, patient tables, etc.

### CAN – Basic Communication Services

The CAN data link layer protocol provides only two communication services: to transmit a message and to request the transmission of a message. The messages are transmitted in broadcast, meaning that any node is allowed to receive any message. Each CAN message is identified by a unique identifier. This identifier is not only used for identification of the message content, but is also assigned with a priority. This priority is used to arbitrate bus access in the case of two or more nodes wanting to access the physical layer at the very same moment.

If the central processing unit (CPU) of a given station wishes to send a message to one or more stations, it passes the data to be transmitted and the identifier to the assigned CAN chip. This is all the CPU has to do to initiate data exchange. The message is constructed and transmitted by the CAN chip. As soon as the CAN chip receives the bus allocation, all other stations on the CAN become receivers of this message. Each station in the CAN, having received the message correctly, performs an acceptance test to determine whether the data received is relevant for that station. If the data is of significance for the station concerned, it is processed, otherwise it is ignored.

Figure 1: CANopen Device Model



For the data to be processed in realtime, it must be transmitted rapidly. This not only requires a physical data transfer path with up to 1Mb/s, but also calls for rapid bus allocation when several stations wish to send messages simultaneously. Bus access conflicts are resolved by bit-wise arbitration on the identifiers involved, by each station observing the bus level bit for bit.

In accordance with the 'wired and' mechanism, by which the dominant state (logical 0) overwrites the recessive state (logical 1), the competition for bus allocation is lost by all those stations with recessive transmission and dominant observation. All 'losers' automatically become receivers of the message with the highest priority and do not reattempt transmission until the bus is available again.

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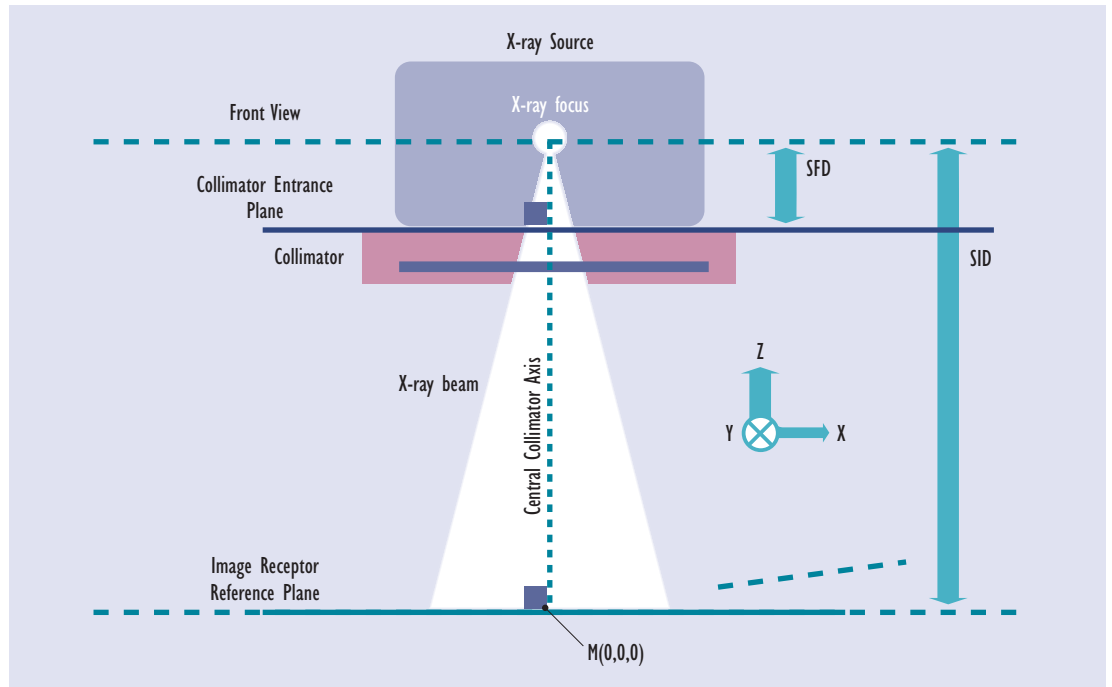
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**Figure 2: Collimator Co-ordinate System**

The individual co-ordinates are seen from a front view.

### CANopen Application Layer

The CANopen application layer and communication profile were originally developed as a standardised embedded network with high flexible configuration capabilities. CANopen unburdens the developer from dealing with CAN-specific details such as bit timing and implementation-specific functions.

CANopen provides standardised communication objects for realtime data (process data objects (PDOs)), configuration data (service data objects (SDOs)) and special functions (time stamp, sync message and emergency message) as well as network management data (boot-up message, network management message and error control message). In order to guarantee interoperability, there is a CANopen conformance test tool available from National Instruments. CiA uses this tool for certifying CANopen.

In each decentralised control application, different communication objects are required. In CANopen, all these communication objects are standardised and well described in the object dictionary. The CANopen object dictionary is accessible by a 16-bit index and, in the case of arrays and structures, by an additional eight-bit subindex. The use of an object dictionary allows the specification of objects independent of the CAN identifiers, which is why CANopen can distinguish more than 2,048 objects even if CANopen is based on standard CAN frames with 11-bit identifiers.

CANopen PDOs are mapped to a single CAN frame using all eight bytes of the data field to transmit application objects. Each PDO has a unique identifier and may be transmitted by only one node, but it can be received by more than one (producer/consumer communication). PDOs may be transmitted in different modes, i.e. driven by an internal event, by an internal timer, by remote requests and by a sync message received from a specific node. The default mapping of application objects as well as the supported transmission mode is also described for each PDO in the object dictionary.

PDO identifiers have a high priority to guarantee good realtime performance. If realtime performance is required, the system designer can configure an inhibit time for each PDO. The inhibit time forbids this object to be transmitted within a specific time. A deterministic PDO behaviour can be designed on more than one object.

PDOs are transmitted with no confirmation. Which application objects are transmitted within a PDO are defined in the PDO mapping object. This describes the sequence and length of the mapped application objects.

The CANopen device profiles specify the default PDO mapping. A device that supports dynamic mapping of PDOs must support this during the pre-operational state. If variable mapping during operational state is supported, the SDO client is responsible for data consistency.

### Device Profile for Collimator Devices

In CANopen device or interface profiles, there are defined application objects to achieve a part interchangeability of CANopen devices. CiA has published device profiles for generic input/output (I/O) modules, for drive and motion controllers and for encoders, etc.

The generic collimator, as defined by the CiA WD 412 functional device profile (not yet published), has three basic functions that may or may not be implemented in a specific collimator.

- The main purpose of an X-ray collimator is to limit (or collimate) the X-ray beam issued by an X-ray emitting source (X-ray tube) to a defined receptor format. This specification supports several versions of this collimating function, of which rectangular collimating is the most common.
- In addition, filters may be applied to the X-ray beam in order to influence spectral characteristics of the X-ray beam.
- Finally, visual simulation of the X-ray beam is a functionality that is incorporated in this device profile.

It should be noted that manufacturer-specific functionality might be added to the generic collimator functionality. This functionality does not form part of the generic standard and must be described in the manufacturer's documentation.

The collimator co-ordinate system is shown schematically in *Figure 2*. It is assumed that the X-ray focus is located on the central collimator axis. Should this not be the case, the system is responsible for providing means for correcting this misalignment. The necessary measures are implementation-dependent and go beyond the scope of this functional device profile.

### Summary

The CANopen application layer is the most important standardised CAN-based embedded network. In particular, in medical applications, it has been widely accepted. GE Medical Systems, Philips Medical Systems and Siemens Medical Systems jointly specify the CANopen device profile under the umbrella of the non-profit CiA association.

In order to benefit from a standardised higher-layer protocol, other medical industries are invited to define CANopen profiles for their specific purposes if generic profiles already published do not satisfy application requirements. ■

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