CANopen gateways to the Internet of Things

The CiA organization has started several activities to specify Internet access for CANopen entities. These projects could make CANopen part of the Internet of Things.

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The CiA 309 gateway specification series ("Access from other networks") is suitable for connections between CANopen and TCP/IP-based networks. Therefore it can also be used for the so-called Internet of Things (IoT). The first CiA 309 version, which was defined in 2004, was only used in niche applications but starting in 2012, when the specification was updated, CiA 309 gateways have been in use in a broad range of applications and several hardware and software products are now available. Especially with the Internet of Things more applications have opened up for CiA 309 gateways.

An overview of CiA 309

The CiA 309 specification consists of three parts. The first part, CiA 309-1, describes general services and principles and defines three gateway classes.
Besides these classes, additional CANopen services like PDO, heartbeat consumer, node guarding master, LSS master, and more are defined in CiA 309-1, but those are optional.

The second part, CiA 309-2, defines a mapping of these services to a Modbus/TCP-CANopen gateway. The Modbus/TCP side of the gateway is a Modbus/TCP slave and the CANopen side can either be a simple SDO client or a sophisticated CANopen manager depending on the implemented gateway class. Nevertheless, the Modbus/TCP-CANopen gateway has to work within the limitations of existing Modbus

Table 1: CANopen gateway classes

Class 1	NMT Slave + SDO Client
Class 2	Class 1+ SDO requesting device
Class 3	CANopen Manager

Figure 1: Modbus/CANopen gateway message structure

networks, which means that the length of requests and responses is limited to 253 bytes and that asynchronous data transfers (e.g. PDOs) are not allowed. Modbus messages to Modbus/CANopen gateways are transmitted using the Modbus Encapsulated Interface Transport (MEI) with the function code 43 and the MEI type 13. The 2 bytes are followed by CiA 309-2 commands as binary data.

CiA 309-3 defines an ASCII mapping of the CANopen services and all CANopen services can be transmitted as ASCII strings via TCP/IP. Nevertheless, the protocol definition does not limit the use of TCP/IP as transport layer, so also implementation that use UDP/IP or a serial point- to-point protocol are possible and in use.

The specification basically covers four service primitives. These are:

◆ Request: communication service required;
◆ Confirmation: answer to a service request;
◆ Indication: an event has occurred in the network;
◆ Response: answer to an event.

Based on these, the ASCII protocol for CANopen defines commands that are composed of tokens that are separated by white-spaces and closed by CRLF characters. All commands that are sent to the gateway are confirmed and preceded with a sequence number that is enclosed in square brackets [ ]. The sequence number is an Unsigned32 number and this number is sent back from the gateway with the answer, but it is not used with event-triggered messages from the gateway. After the sequence number

the command starts with an optional net-ID and the node-ID, which is addressed and followed by the specific command. All commands are defined in CiA 309-3 Backus–Naur Form (BNF). The definition for a SDO request is e.g.:

```
"["<sequence>"]"  [[net] node]
r[ead] <multiplexer> <datatype>
```

and an example for such a request is:

```
[2232] 1 43 r 0x1000 0 u32
```

which means that the value of the object 0x1000 subindex 0 shall be read from node 43 in net 1. If a CiA 309-3 gateway only supports a single CANopen network, the net number can be omitted.

In the last meeting of the CiA 309 working group it was decided to open the specification for more complex commands. Although nothing has been defined yet, the decision paths the way to more sophisticated use cases, which might be necessary for the Internet of Things.

Modbus/TCP and ASCII gateways

Emtas provides both a CiA 309-2 gateway to connect Modbus/TCP to CANopen networks and a CiA 309-3 gateway for TCP/IP connections using ASCII commands. The CANopen component of the gateways is based on the CANopen master stack from Emtas. The CiA 309 gateways are available as Linux applications and can be used with an (embedded) Linux device that supports a can-4linux or SocketCAN interface. Also, a source code edition is offered that can be ported to all targets that support a CAN interface and a TCP/IP stack. Fully ▷

featured TCP/IP stacks with BSD sockets facilitate the use, but light-weight TCP/IP stacks without BSD socket support can also be used. Thus the source code edition is suitable for integration into small embedded devices. Additionally, using the source code it is possible to add functions and services that exceed the scope of the CiA 309 specification.

Current use cases of CiA 309

One of the first use cases of CiA 309 were CANopen service and diagnostic tools that could operate via Ethernet or Internet connections. The first product that implemented CiA 309 (specifically CiA 309-3) in hardware was Ether-CAN, developed and manufactured by the company EMS Wünsche from Germany. Besides CANopen tools, the CANopen specification 443 for subsea instruments specifies the use of CiA 309-3 for a transparent maintenance link to configure or update devices. More applications exist as backbones and configuration links to handle parameterization and firmware updates, but they haven't been specified in CANopen application profiles yet.

Figure 2:   Gateway service primitives

Use cases of Internet of Things

According to Wikipedia, the Internet of Things (IoT) refers to the interconnection of uniquely identifiable embedded computing-like devices within the existing Internet infrastructure. Typically, it is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communication (M2M) and covers a variety of protocols, domains, and applications.

In our CANopen world, the IoT means to get Internet access to CANopen networks and even single CANopen devices.

CAN in Automation recently established a working group that deals with the Internet of Things. Employees of Emtas participate in this group. Unfortunately, these experts have just started working on the topic and consequently there are no results available yet. During the first meetings, use cases have been defined: Diagnostics of devices and functional addressing. Functional addressing means that a CANopen device is no longer addressed by its CANopen node-ID but instead by a functionality, e.g. "Temperature sensor 4" or

a unique function code that represents the functionality. This will not be limited to the scope of nodes but will also cover parameters and data that are normally addressed by an index and a sub index.

Additionally, it was discussed that there should be different types of CANopen devices with different IoT capabilities:

- CANopen devices with full Ethernet capabilities that might be able to be a web server themselves;
- CANopen devices with limited IoT capabilities that can only respond to a restricted set of IoT requests;
- CANopen devices without IoT support – classic CANopen devices which have to be addressed via an intelligent gateway.

Up to now the preferred method to retrieve data via an Ethernet network is to use dedicated HTTP requests, which are tunneled via CANopen networks using existing CANopen services. For all use cases and applications, LAN and WLAN access must be enabled and security considerations have to be taken into account as well.

CiA 309 and Energybus

The topic Internet of Things is also being discussed within Energybus, which has developed the CiA 454 application profile for use in light-electric vehicles and other energy management networks. Without ready solutions from the CANopen SIG "Internet of Things", own discussions have been started that led to a first proposal. A current idea is to extend CiA 309 to use cases of Energybus. As discussed within the SIG, a functional addressing scheme must be added to the geographical addressing CANopen provides today. Mapped to CiA 309 this means:

- Usage of device or function names instead of node-IDs: e.g. Battery_2 instead of Node-ID 31;
- Usage of parameter names instead of index/ sub-index addressing;
- Addressing data instead of PDOs;

The usage of device names instead of node-IDs is especially important in CiA 454 (CANopen profile for energy management systems) networks. In this profile, node-IDs are usually assigned dynamically using the Layer Setting Services (LSS).

Additionally, it was proposed that a CiA 309 gateway should only transmit PDO data via TCP/IP if any values have been changed. When this is taken into account, an additional update timer is necessary to ensure that even clients that are connected later can get informed about current, but slowly-changing values. Instead, a "Request PDO Values" service could be added to CiA 309 gateways. Mapped to CiA 309-3 these new commands look like these:

```
Value Read Request similar to
SDO read request
"["<sequence>"]" <device>
r[ead] <parameter_name>
example:
>[1234] BATTERY_2 r
rated_voltage
<[1234]] 4800

Value Write Request similar to
SDO write request
"["<sequence>"]" <device>
w[ead] <parameter_name>
<value>
example:
>[815] MCU w assistance_level 2
<[815] OK

Value Registration
"["<sequence>"]" <device> reg-
ister value <parameter_name>
example:
>[4711] BATTERY_2 register
value current_voltage
<[4711] OK

Value Indication
value <parameter_name> <value>
example:
<VALUE BATTERY_2 current_
voltage 4761
```
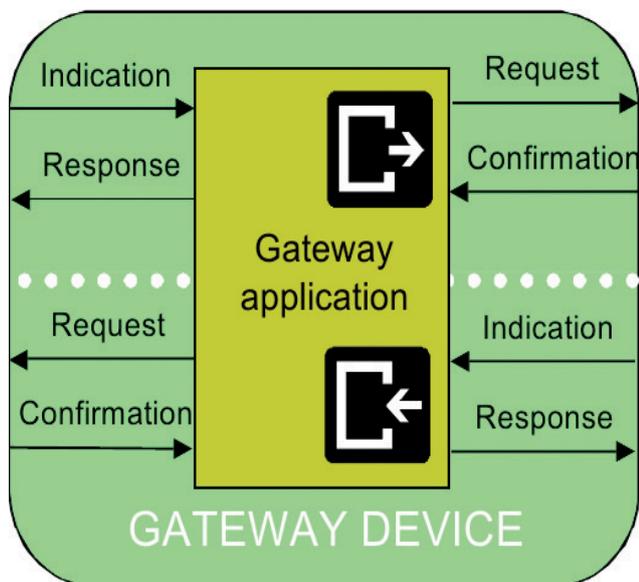
One of the objectives of that approach is for smartphone applications to be able to read/write certain information from an electric bicycle without having to know much about CANopen or Energybus (CiA 454) whereas more sophisticated applications or PC tools could use the full features of CiA 309-3.

Using such an approach, an extended CiA 309 gateway in an Energybus network has to be aware of the characteristics of CiA 454 devices and the structure of the network. Thus an extended CiA 309-3 gateway for Energybus would have to be located inside the Energybus Controller, which is the virtual device that controls the Energybus network. Besides CiA 309-3 other methods like HTTP-POST requests or more specific JSON or XMLHttpRequest requests have been considered as well. For the sake of backward compatibility these approaches were rejected for the time being in favor of extending CiA 309-3. Nevertheless this decision could be reversed if the SIG "Internet of Things" comes up with a better generic approach that fits the needs of most CANopen users.
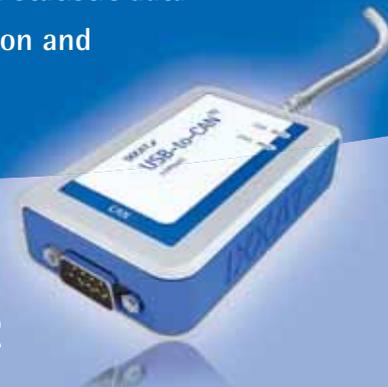
The proposed idea to extend CiA 309 will suit the needs of the author for the use case in Energybus (CiA 454) networks. On the one hand, the CiA 454 approach could be used for a broader range of applications, but significantly more examinations have to be done beforehand. On the other hand, the work started by the CiA working group shows promising approaches. Interested parties are welcome to join the efforts to develop a generic solution for the Internet of Things even beyond the current scope of CANopen.　◄

References
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