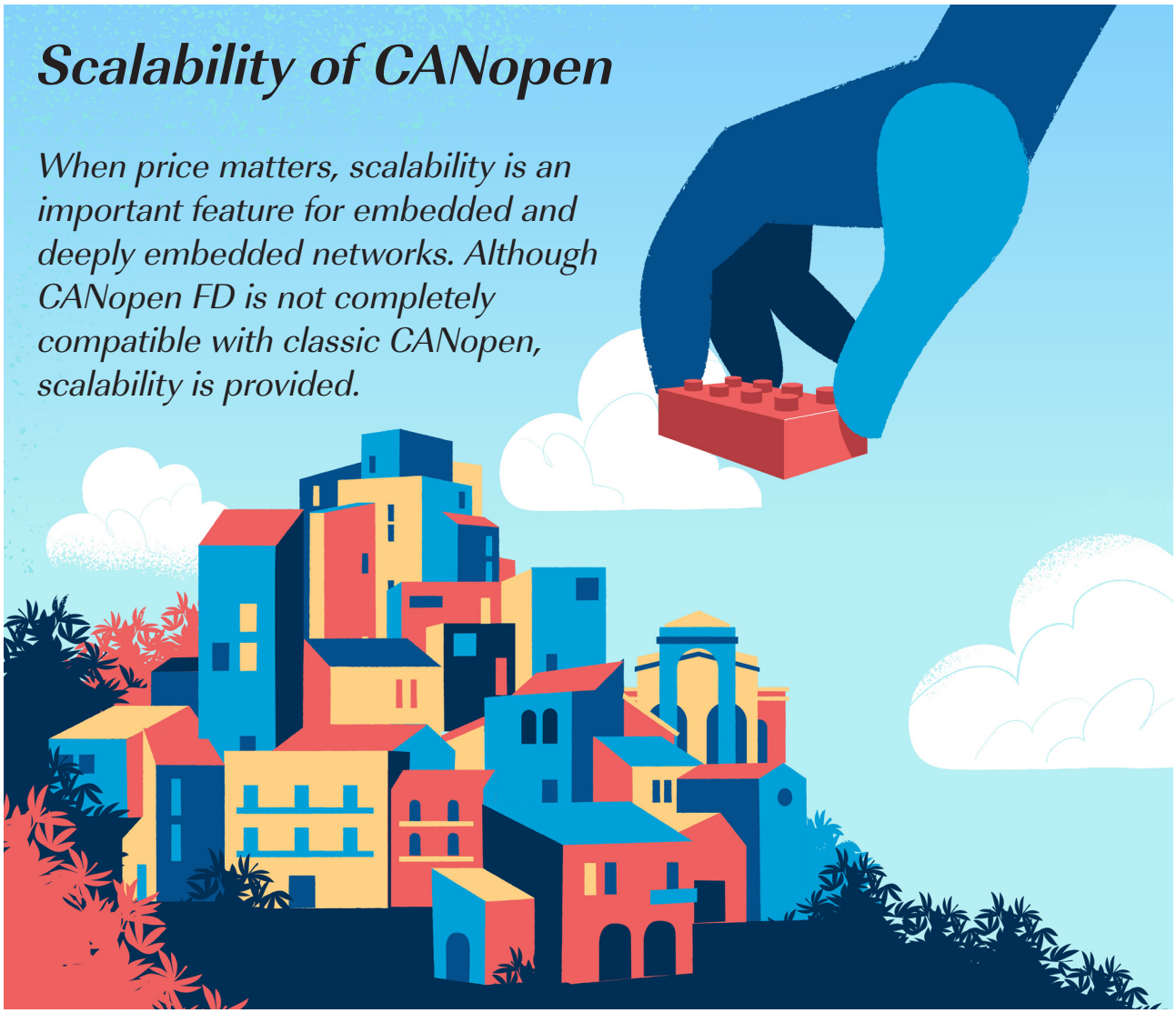
Scalability of CANopen

When price matters, scalability is an important feature for embedded and deeply embedded networks. Although CANopen FD is not completely compatible with classic CANopen, scalability is provided.



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Classic CANopen embedded networks are used in a very broad range of application fields: Just have a look into previous issues of this magazine and its online sister publication. You will find reports about CANopen in satellites, in subsea, any kind of vehicle, and many motion-control applications. Additionally, CANopen has migrated into deeply embedded networks such as backbone networks, in industrial I/O devices, and in smart devices with multiple sub-modules. CANopen introduced already in 1994 offered from the beginning scalability not only regarding communication functionality.

Some people still think that CANopen is complex. No, it is not. It provides just a few mandatory features (NMT, Heartbeat, and expedited SDO functionality), and a lot of optional add-on communication functions (PDO, normal SDO, SYNC, TIME, and EMCY as well as “Flying” NMT master functionality), if needed. This is like in a restaurant: the menu lists more dishes than you can eat.

Regarding the bit-rate, CANopen allows eight standardized bit-rates; from 10 kbit/s to 1 Mbit/s. Other communication technologies do not support those much different bit-rates. But consider: The higher the speed, the more challenging is the physical network design. This means the costs for cabling, connectors, and energy consumption increase with the higher bit-rates.

On the other hand, data throughput requirements are increasing permanently with new control functions. Of course, you can spend some effort to communicate smartly, not wasting the available bandwidth. For example, do not talk, if you have no new data. But at some point you need more throughput. The limit for classic CANopen is 1 Mbit/s, when your network is not longer than 25 m and only very short not terminated stubs are installed.

CANopen FD for higher bit-rates

CANopen FD is based on the CAN FD data link layer. Depending on the bus-line topology you can achieve 2 Mbit/s in the data-phase. If you need more, you should implement the so-called SIC (signal improvement circuit) transceiver as specified in CiA 601-4 version 2.0.0. Up to 8 Mbit/s is possible, when the topology is as close as possible a bus-line and the impedance of the installed components matches 120 Ohm. For more details on SIC transceiver, see the article on page 4.

In some applications, the busload is not the restriction. It's the 8-byte payload limit, which matters. CANopen FD features because of the used CAN FD data link layer a maximum data frame length of 64 byte. Unfortunately, the length is not byte-wise increasable. The longer data ▷

frames can be used to add cybersecurity or functional safety headers/trailers. This means your network can be scaled regarding security and safety requirements without changing the normal process data communication.

In case, you do not need higher bit-rates than 1 Mbit/s, you can use in arbitration and data-phase the same bit-timings. Depending on the chosen topology, it could be that you should implement different sample-points.

As said above, higher data-rates require a more precise development of the physical network. This means, try to avoid communication of redundant data. This reduces the busload allowing the use lower bit-rates.

Table 1: Classical CAN bit-rates, which also can apply for the arbitration bit-rate in CANopen FD, but the sample-point shall be set to 80 %

Bit-rate [kbit/s]	Max. network length [m]	Sample-point [%]
1000	25	75 to 90
800	50	
500	100	85 to 90
250	250	
125	500	
50	1000	
20	2500	
10	5000	

Table 2: CAN FD dataphase bit-rates using an 80-MHz clock frequency

Bit-rate [Mbit/s]	Sample-point [%]
10	62,5
8	60
5	62,5
4	70
2	75
1	80

Optimized PDO communication

The classic CANopen and CANopen FD application layers are designed to support scalable PDO (process data object) communication. The PDO protocol allows the transport of 1-byte messages up to 8-byte (classic CANopen) respectively 64-byte (CANopen FD) messages. For messages with more than 8 byte the scalability is not byte-wise, but with some jumps: 12, 16, 20, 24, 32, 64 byte. If not the entire payload is needed, so-called padding bytes need to be used.

Regarding the PDO scheduling both application layers support periodical, change-of-state, and synchronized transmission. And the best is, you can mix them in the network. Combined with the option to configure PDO cross-communication between NMT slave devices, the system designer can scale the PDO communication to the application needs. This means you can start with simple “master/slave” communication scheme and end-up with a highly optimized PDO communication. Sophisticated CANopen system design tools can do this optimization.

From SDO to USDO

Scalability of SDO (service data object) communication was already provided from the beginning. Expedited SDOs enable to read or to write parameters with a maximum length of 4 byte in the object dictionary of another device. Using the normal SDO protocol, the length of the parameters is not limited. In order to accelerate the SDO transport protocol, the SDO block transfer was introduced in classic CANopen version 4.0.

CANopen FD supports similar scalability of USDO (universal service data object) communication. Additionally, the USDO protocols can be broadcasted, what is not possible with SDOs. In the near, future also multi-parameter transmission will be possible with USDOs. A typical application is the PDO mapping configuration with one USDO. In the past, you needed for each PDO mapping parameter individual SDO/USDO messages. The single message approach avoids considering configuration inconsistence caused by SDO communication problems.

From simple to complex networks

Classic CANopen and CANopen FD are designed to support scalability. You can start with a simple network, just using expedited SDO/USDO communication. You can add normal SDO/USDO communication and simple “master/slave” PDO messages. If one network is not sufficient, you can design a multi-segment network. Necessary remote access (router function) is already available in the portfolio of the SDO/USDO protocols.

Scalability is an important issue in modern communication systems. Classic CANopen and CANopen FD are very scalable compared to other standardized CAN-based higher-layers such as SAE J1939. The Classical CAN and CAN FD data link layers are backwards compatible, but legacy Classical CAN controllers destroy CAN FD data frames by means of CAN error frames. This means, new protocol controllers supporting CAN FD are necessary. ◀

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