Kvaser Air Bridge System Integration Guide

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1 About this document

This document provides guidance for integrating the Kvaser Air Bridge units into different system environments. It consists of an introduction to Kvaser Air Bridge, followed by integration guidelines that aim to give you a complete understanding of how to adapt to the Kvaser Air Bridge in an optimal way in order to maximize the performance of your application. Use Section 3, Design-in guidelines, on Page 7 when designing-in Kvaser Air Bridge to a new application.

A complementary document, the Air Bridge Installation Guide, provides installation advice for end-users who use Kvaser Air Bridge and want to optimize radio performance and reach.

2 Introduction

2.1 What is Kvaser Air Bridge?

The Kvaser Air Bridge is a CAN system bridge that can be used to transfer messages wirelessly between two CAN systems.

Kvaser Air Bridge consists of a pair of preconfigured radio transceivers operating in the so-called 2.4 GHz ISM band. This is an unlicensed frequency band open for applications in industry, science and medical sectors. Equipment using this frequency band includes mobile phones, computers, wireless access points, car alarms, garage door openers, remote-controlled machinery etc.

2.2 How does Kvaser Air Bridge work?

The Kvaser Air Bridge can be used in many situations to bridge two CAN systems. All that's required is to connect the two preconfigured radio transceivers to each of the systems.

All Kvaser Air Bridge units include a radio transceiver with a power amplifier that provides the maximum allowed transmit power, ensuring a robust connection and maximizing the communication distance potential. The omni-directional antennas enable transmission and reception in any direction. Provided that the Kvaser Air Bridge unit is mounted in an upright position, 360-degree coverage can be obtained.

2.3 Spectrum availability and co-existence

As the 2.4 GHz ISM band is made available for many different radio technologies, it is subject to various rules that aim to establish co-existence in areas that are densely populated with transmitters and receivers using the same frequency band. Such rules include spreading the radio energy across the frequency band and preventing simultaneous transmission by radio equipment in close vicinity of each other. It's important to note that although the 2.4 GHz ISM band serves to promote co-existence between radio transceivers, there may be situations where degraded radio communication is experienced.

The Kvaser Air Bridge employs special features to make it a robust radio link, most notably a frequency hopping approach that uses around 40 frequencies. Besides frequency hopping, a special 'Listen Before Transmit' mechanism invokes a 'Clear Channel Assessment' before every transmission. If another radio is located nearby the Kvaser Air Bridge unit and transmits on the designated frequency, then the data will not be transmitted on that frequency but rather on the next available frequency. This latter mechanism is not mandatory in the United States and is therefore not implemented in units sold there.

2.4 CAN connection

The Kvaser Air Bridge provides a simple approach that preserves many CAN bus features, and it automatically adapts to the CAN bus bit rates.

As the transfer of messages over radio always introduces a certain latency, it cannot support arbitration between the CAN systems. This means that a message sent on one CAN bus will be subject to a second arbitration on the other CAN bus after being transferred over the radio link. On the other hand, all messages received on the Kvaser Air Bridge's own CAN bus interface will be directly acknowledged according to the CAN standard, i.e. even before they are transmitted to its paired Kvaser Air Bridge unit.

Autobaud is the process of automatically selecting the correct bus parameters for communication on the connected CAN bus based on received CAN traffic.

2.5 Transmission and reception of messages over radio

As with any radio-based system, a careful and sound installation approach will ensure optimal communication. This concerns the surrounding structures, in addition to other emitters that may disturb the radio communication. Near-by devices may also be using the 2.4 GHz ISM band, or there may be apparatus unintentionally emitting energy in this band.

The Kvaser Air Bridge units take turns in transferring messages over the 2.4 GHz ISM band. The transfer is based on a Time Division Duplex protocol with a fixed cycle length of 4.8 ms of which each Kvaser Air Bridge unit is allocated 50%. The 2.4 ms transmit interval in each direction provides adequate time for the transmitter and receiver to reliably synchronize and transfer the messages at short latency. For each transmit interval, a new frequency is selected according to a frequency hopping scheme that ensures equal use of the available frequencies. The Kvaser Air Bridge automatically establishes the radio link between Kvaser Air Bridge units and has the ability to avoid transmitting on frequencies presently used by other nearby radio devices.

In scenarios involving multiple pairs of Kvaser Air Bridge units, it is recommended that all units use the same firmware version to optimize performance. Please contact Kvaser support for more information.

3 Design-in guidelines

To highlight the benefits of the Kvaser Air Bridge as a system component, the following 'design-in guidelines' serve to help a system integrator to optimize performance for different use cases. The Kvaser Air Bridge system exhibits characteristics that make it especially suitable for:

- Remote control systems
- Supervision systems
- Provisioning of data
- Diagnostics

Data communication is essentially about capacity and timing characteristics. It is important to understand the possibilities and limitations of radio-based data links and networks and to relate these to the overall system requirements and use case. Just as important is a good understanding of the CAN protocol, in particular arbitration and acknowledge mechanisms, error frame handling and bus load impact.

Critical systems may need special precautions to be taken to ensure a robust and safe system design and development programs may require special procedures to be strictly followed. The below recommendations provide guidance of how to make the most out of the Kvaser Air Bridge.

Rule 1. Enable correct start-up

As soon as both Kvaser Air Bridge units have been powered up, they start the radio link establishment procedure. Once the radio link between the Kvaser Air Bridge units has been established, they will be ready to transfer messages between their respective CAN systems, i.e. provided that Autobaud Detection has completed successfully.

The Autobaud Detection requires that messages are transmitted onto either of the CAN systems by another CAN node. If no supported CAN bus bit rate has been detected by a Kvaser Air Bridge unit within 15 seconds after radio link has been established, it will select the same bit rate as the other unit. If neither Kvaser Air Bridge unit has detected a supported network bit rate bit rate within 15 seconds after power up, the Autobaud Detection will be governed by whichever Kvaser Air Bridge unit detects CAN network bit rate first. There is no limit to the time that the Kvaser Air Bridge units will wait for a message on their CAN systems.

Should the radio link for some reason be interrupted, it will automatically be reestablished without the need for renewed Autobaud Detection.

Rule 2. Limit the message rates

The transfer capacity of the Kvaser Air Bridge is approximately 1500 messages per second in each direction. The transfer capacity of the Kvaser Air Bridgedefines the maximum number of messages generated by the nodes on each CAN system.

It is an advantage if the number of messages can be kept somewhat below this capacity to account for possible causes of interference, such as occupied frequencies. An adequate margin could be 20%, for example, in relation to the Kvaser Air Bridgetransfer capacity given in Section 4.2, Transfer capacity, on Page 10.

Different approaches may apply for different use cases. For some applications, a flow control mechanism may be suitable. For others, the message rate needs to be defined for every CAN node.

Rule 3. Choose appropriate CAN bus bit rates

The bit rates on the connected CAN buses do not need to be the same. The Kvaser Air Bridge does not have a default bit rate but enables each unit to independently select any of the following CAN bus bit rates:

- 125 kbit/s
- 250 kbit/s
- 500 kbit/s
- 1000 kbit/s

A high bit rate gives an advantage concerning latency related to arbitration and message transfer on the CAN buses. Also, a high bit rate means that the Kvaser Air Bridge radio packets are used more efficiently. Generally, a bus load of less than 50% is recommended.

Rule 4. Limit message bursts

The maximum number of messages within a short period that are transferred to the Kvaser Air Bridge unit on the local CAN bus may need to be limited in order to prevent an overflow in the transmit buffer, as this would lead to all messages in the buffer being discarded. If a flow control mechanism is implemented, it should address the message bursts

A message burst can be defined as a higher-than-average message rate that endures over a short time period. The number of messages sent over a certain time period can be used to control such message bursts.

The burst is limited by the transmit buffer size (128 messages) and the Kvaser Air Bridge transfer rate (8 messages in 4.8 ms). Hence, the maximum number of messages within a certain period should be as follows:

$$
\begin{aligned}
N_S &< 128 + N_C \cdot T_d \\
T_d &= \text{Duration in seconds} \\
N_S &= \text{Number of messages sent in } T_d \\
N_C &= \text{Transfer capacity in messages per second}
\end{aligned}
$$

(see Section 4.2, Transfer capacity, on Page 10)

For example, a maximum of 200 messages should be sent in 50 ms. After such a burst, the average message rate will need to be recovered by lowering the number of messages transferred.

Rule 5. Make sure latency can be handled

Although the average transfer latency introduced by the Kvaser Air Bridge is normally 4.8 ms, there is a slight probability that a packet cannot be correctly transferred and thereby retransmits. At most, a message in the Kvaser Air Bridge will retransmit twice before being discarded. Because retransmissions are expected to occur seldomly,the average transfer latency introduced by Kvaser Air Bridge would normally be around 5 ms.

Additional latency may result from retransmissions due to interference by nearby emitters and from weak radio signal caused by long distance or poor propagation conditions.

Kvaser Air Bridge will introduce additional transfer latency for each retransmission required. The latency will return quickly to normal when the interference disappears or when propagation conditions improve.

Rule 6. Ensure resilience to packet loss

Applications must take into account the probability of lost messages over the Kvaser Air Bridge, as with any radio-based data link. Depending on the type of information conveyed in a message, the message loss should be handled in different ways.

Applications may, for example, have to incorporate a transport protocol to ensure that the transmitted messages are received correctly. Such a protocol must consider the round-trip latency, which besides latency introduced by the Kvaser Air Bridge system, also includes application response time, transfer latency related to the message lengths and any other kinds of latency that may occur in conjunction with arbitration on the local CAN buses.

In case an application employs so called ‘heart beat’ messages and such a message is lost, there is a risk of a false alarm issued by a corresponding supervisory mechanism. Therefore, the heart beat interval may need to be shortened so that the alarm timeout period encompasses at least two intervals. Alternatively, the timeout period can be lengthened provided that the supervision response time is acceptable.

4 Message transfer considerations

The recommendations relate to aspects discussed specifically below.

4.1 Degradation aspects

As described earlier, interference or low signal level may result in a disturbed radio signal but not necessarily loss of messages. That is because a transmitting Kvaser Air Bridge unit will automatically retransmit packets that haven't been acknowledged by the receiving Kvaser Air Bridge unit. Retransmission and related buffering will lead to an increase in latency and as there is a limit to how many times a certain packet may be retransmitted, there may be situations in which messages are eventually lost because of interference. The loss of messages in such a situation would be detected as part of a transport protocol implemented on a higher level.

4.2 Transfer capacity

There is also a limit to how many messages can be transferred between two Kvaser Air Bridge units, its transfer capacity, but this is also limited by the bit rate of the connected CAN systems. Assume for example that one of the CAN systems has a lower bit rate than the other, then it is the lowest bit rate that limits the overall throughput. Both CAN systems must, however, be able to handle the total number of messages transferred within the system.

The transfer capacity of the Kvaser Air Bridgedepends on the size of the payload (up to 8 bytes per message) and on the length of the CAN identifier field (11 bits or 29 bits). For a maximum payload size, the transfer capacity is approximately 1500 messages per second for standard 11 bit identifier CAN frames, and approximately 1100 messages per second for 29 bit identifier CAN frames. The transfer capacity increases when the payload size is reduced. With a minimum payload size, the transfer capacity increases by a factor of three for 11 bit CAN identifier frames, and a factor of two for 29 bit CAN identifier frames.

4.3 Retransmission

As explained above, interference or low signal level may result in some messages experiencing more latency than others as a result of retransmission and related buffering. The order of the messages is kept and the maximum number of retransmissions would normally limit the latency for each individual message. However, nearby emitters very close to the transmitter may occupy some frequencies, preventing transmission or retransmission from taking place on those frequencies. Each Kvaser Air Bridge unit therefore contains a transmit buffer with space for up to 128 messages.

4.4 Transmit buffering

Depending on the number of messages on the CAN bus in relation to the throughput between Kvaser Air Bridge units, there is also the possibility of overflow of the internal transmit buffer in the Kvaser Air Bridge unit. In such a situation, all 128 messages in the transmit buffer will be discarded. As long as the transmit buffer has not become full, it is always the oldest message that is transmitted first.

4.5 Receive buffering

Similar considerations are also relevant for the Kvaser Air Bridge unit that is receiving information. A Kvaser Air Bridge unit includes a receive buffer from which messages are transferred from the local CAN bus. The messages in the receive buffer could be discarded only in the case of of very high bus load.

4.6 Latency

The latency of transferred messages introduced by Kvaser Air Bridge is normally 5.5 ms $\pm$ 2.5 ms. This partly relates to message processing but more importantly to the 4.8 ms transmission cycle which accounts for 4.8 ms $\pm$ 2.4 ms, depending on the moment in time when the message is sent on the CAN bus. If the radio transfer is subject to interference, this may result in an additional 4.8 ms or 9.6 ms caused by retransmission. If a Kvaser Air Bridge unit is prevented from transmitting (by other signals from nearby radios) there will be additional latency. Likewise, if the transmitting Kvaser Air Bridge unit does not receive an acknowledgement from the other Kvaser Air Bridge unit, it will retransmit the respective message before proceeding with transmission of the following messages.

As for all CAN bus systems, arbitration may cause additional latency depending on bit rate on the CAN buses and lower bit rate means a longer time to transfer messages over the CAN bus.

5 Version history

Version history for document IN_98227_air_bridge_system_integration_guide:

Revision	Date	Changes
1.0	2020-11-09	Initial revision