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Stack Implementation for KNX-RF

Abstract
KNX is the abbreviation of Konnex, the most established standard for home and building electronic systems. The Konnex technology is based on the well-tried EIB-System (European Installation bus) with his media twisted pair and powerline. An essential extension now is the wireless alternative KNX-RF (Konnex radio frequency). This contribution gives a short overview about the new application areas, the technical properties and about available hardware and software solutions.

1 Application area

The application area of Konnex-RF is very similar to the use cases of the existing media. So it can be used to control lighting, shutters or heating and cooling. In locations suitable for neither twisted pair cabling nor powerline technology, KNX-RF is used for wireless data transmission within a building.
As the complete Konnex standard also the wireless part KNX-RF is vendor independent. The configuration of KNX-RF devices can be done without using a PC or a laptop. Already available on the market are devices from Siemens (Gamma wave) and Hager (Tebis TX).

2 Protocol

2.1 Addressing scheme

The addressing scheme is based on the one used for twisted pair, which uses individual addresses and group addresses (each 2 bytes). The individual address is a single cast address and is mainly used for configuration purpose. Group addresses are used for runtime communication. The group address 0x0000 is reserved for broadcast addressing.

As RF is an open medium like powerline, a domain address (6 byte, programmable) has been added to separate different neighbouring installations. Unidirectional devices can not be programmed and therefore are not able to use a common domain address. So group telegrams contain the serial number of the sender. The serial number together with the 2 byte group address is called an extended group address. Whereas in twisted pair and powerline the sender as well as the receiver has to be programmed to build a link, in KNX-RF only the receiver has to be configured.

2.2 Physical Layer

The physical layer of KNX-RF is specified according to the regulations for short range devices. Implementations are not forced to use special components. Currently there are different chips available which can be used to build compliant devices.

Technical data for KNX-RF:

- Centre frequency: 868.3 MHz
- FSK Deviation: +-50 kHz
- Transmission power: 1-25 mW
- Duty cycle: 1 %
- Modulation: FSK
- Coding: Manchester
- Chip rate: 32.768 cps

The medium of KNX-RF is very reliable. The used frequency band is not as noisy as the alternative frequencies (e.g. 433 MHz). Compared to the new band in 2.4 GHz devices using 868 MHz show a better transmission behaviour within buildings.

2.3 Link Layer

The frame format of KNX-RF consists of multiple elements. Each telegram starts with a pre-header, which is used for the synchronisation of the receiver.

Preheader		
Preamble	Manchester violation	Sync word
15x ‘01’ chip	‘000111’	‘011010010110’

KNX-RF pre-header

After the pre-header the first data block follows with some control information and the serial number or the domain address. The first block has a fixed length of 10 data bytes and an own checksum of 2 bytes.

Block 1											
Length	C-Field	Esc	Ctrl	SN	SN	SN	SN	SN	SN	CRC hi	CRC lo
0x11	0x44	0xFF	0x03								

KNX-RF data block 1

The application data starts in block 2, which has a maximum length of 16 byte plus 2 bytes checksum. For longer telegrams additional blocks may follow. The coding of the data in block 2 and following are according the telegram format used for twisted pair and for powerline.

Block 2											
KNX-Ctrl	Src hi	Src lo	Dst hi	Dst lo	L/NPCI	TPCI	APCI	Data	...	CRC hi	CRC lo
0x00	0x05	0xFF	0x00	0x01	0xE6	0x00	0x81				

KNX-RF data block 2

It is remarkable that each block contains a separate checksum. The used polynomial of $2^{16}+2^{13}+2^{12}+2^{11}+2^{10}+2^{8}+2^{6}+2^{5}+2^{2}+2^{0}$ achieves a hamming distance of 6. Although processing of received data is time-critical due to the relatively high data rate, it is still possible to detect and correct individual bit errors during reception. Consequently, communication quality is very high even when transmission conditions are unfavourable. Assumed a bit error rate BER (here chip error rate) of 10^{-4} the error correction improves telegram success rate from 96.31 % to 99.97 %.

2.4 Network Layer

The network layer for end devices (sensors and actuators) is quite simple. In the receiving direction the network layer only interprets the addressing mode. In the sending direction it builds the link layer request for all kind of frames to be sent.

2.5 Transport Layer

Currently for KNX-RF only the connection-less communication is used. The connection-oriented communication like it is used for management purpose in twisted pair or powerline installations is not foreseen for the wireless medium.

2.6 Session und Presentation Layer

Like for twisted pair and powerline also for KNX-RF session and presentation layer are not defined. The corresponding services according to the OSI/ISO reference model have been moved to the application layer.

2.7 Application Layer

The application layer is splitted in a part for the runtime communication and the device management. The runtime communication uses only the following APCI service (Application Protocol Control Information):

- APCI_VALUE_WRITE

The complex management for KNX-RF used by bi-directional devices includes much more services:

- APCI_PHYS_ADDR_WRITE
- APCI_PHYS_ADDR_READ

- APCI_PHYS_ADDR_RESP
- APCI_PHYS_ADDR_SER_NUM_READ
- APCI_PHYS_ADDR_SER_NUM_WRITE
- APCI_PHYS_ADDR_SER_NUM_RESP
- APCI_DOMAINADDRESS_WRITE
- APCI_DOMAINADDRESS_READ
- APCI_DOMAINADDRESS_SER_NUM_WRITE
- APCI_DOMAINADDRESS_SER_NUM_READ
- APCI_DOMAINADDRESS_SER_NUM_RESP
- APCI_NETWORK_PARAM_WRITE
- APCI_DEVICE_DESC_READ
- APCI_DEVICE_DESC_RESP
- APCI_PROP_VALUE_READ
- APCI_PROP_VALUE_RESP
- APCI_PROP_VALUE_WRITE
- APCI_PROP_DESC_READ
- APCI_PROP_DESC_RESP
- APCI_FNCT_PROP_CMD
- APCI_FNCT_PROP_STATE_READ
- APCI_FNCT_PROP_STATE_RESP

This leads to a quite complex software implementation of bi-directional devices. Against this the code size of unidirectional devices is hardly reduced, as this devices do not need the handling of all this services.

3 Configuration Modes

Konnex defines not only different media, but also different configuration modes. In principle any combinations between a configuration mode and a medium is valid. For KNX-RF only the easy mode is used, but the system mode is already implemented in the devices.

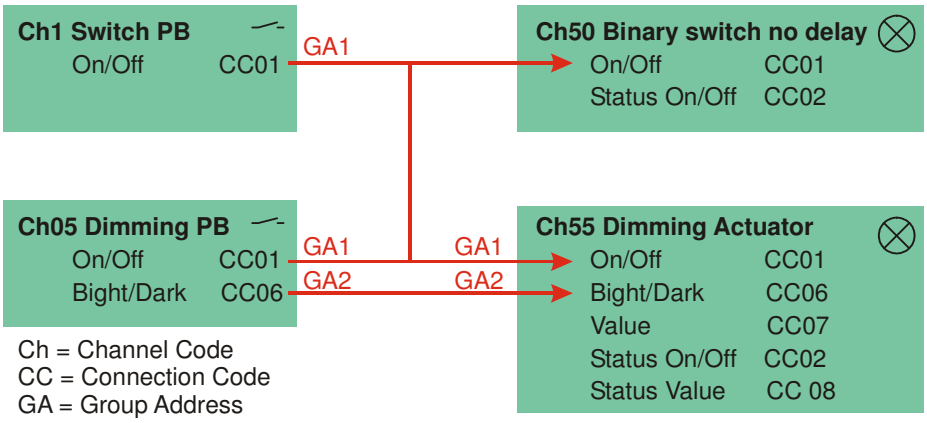
3.1 System Mode (S-Mode)

The system mode describes the configuration process using a PC. Because of the very powerful user interface of a PC this mode offers the best possibilities to configure a system. Because of the complexity of the system mode, it is foreseen for professional installers. As all currently available devices are s-mode prepared, it will be only a question of time for the release of an appropriate software tool. So it is planned to implement the KNX-RF support into the ETS (EIB Tools Software).

3.2 Easy Mode (E-Mode)

The target of the easy mode is the configuration without using a PC. A product database like it is used for ETS is not necessary. All information needed to program a communication

partner is stored in the devices. The easy mode configuration is divided into several sub modes. Siemens uses for KNX-RF the push button mode, the configurator from Hager uses the features of the controller mode.



Example of an easy mode installation

4 Device models

To achieve an interworking between devices of different manufacturers it is essential, that they are not only using the same protocol but also support a well defined set of management services. For that reason different device models have been defined as so called profiles.
The KNX-RF standard differentiates between unidirectional (send only) and bidirectional devices, which also contain a receiver. As unidirectional devices have no receive which is permanently on, they can be realized with very low power consumption and are suitable for battery driven devices. Actuators of course are always bidirectional and are in most cases powered by mains. The following device model are defined for KNX-RF

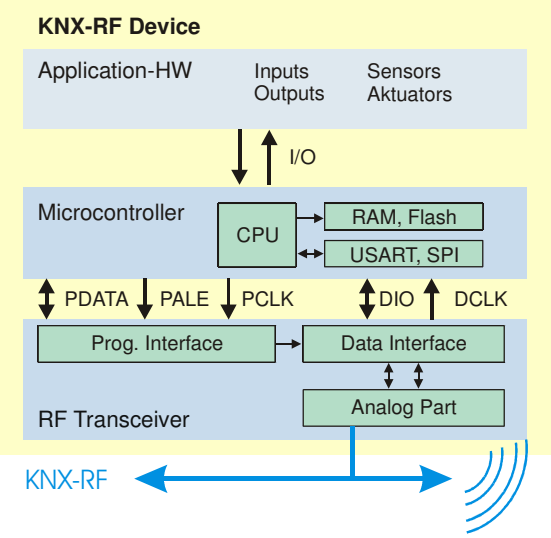
- 2010 (bidirectional)
- 2011 (unidirectional)

All currently available KNX-RF can be configured without a PC using the easy mode. However there is a difference between different easy modes. Using the easy push button mode it is possible to link for example a sensor and an actuator without any additional resources. It is only necessary to activate both devices into the learning mode and the link is established. For the easy controller mode always a third device, the configurator, is used to program a link.
In complex installation it is difficult with any easy mode to setup the system. Because of the limited user interface the installer has no overview about all installed devices. As alternative the system mode together with a PC or laptop may be used as soon as a program is available.

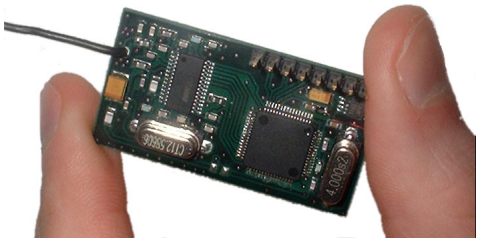
5 Hardware-Architecture

The KNX-RF standard is not based on special components. Currently there are different chips on the market which allow the conformance to the standard. In most cases microcontrollers are used which have a low power consumption. For the interface to the RF medium a trans-

ceiver of a transmitter is used. Dedicated chips for KNX-RF are not yet available but already scheduled. The launch of these components is planned at the end of 2006. This new hardware solution will help to reduce the costs of both development and production.



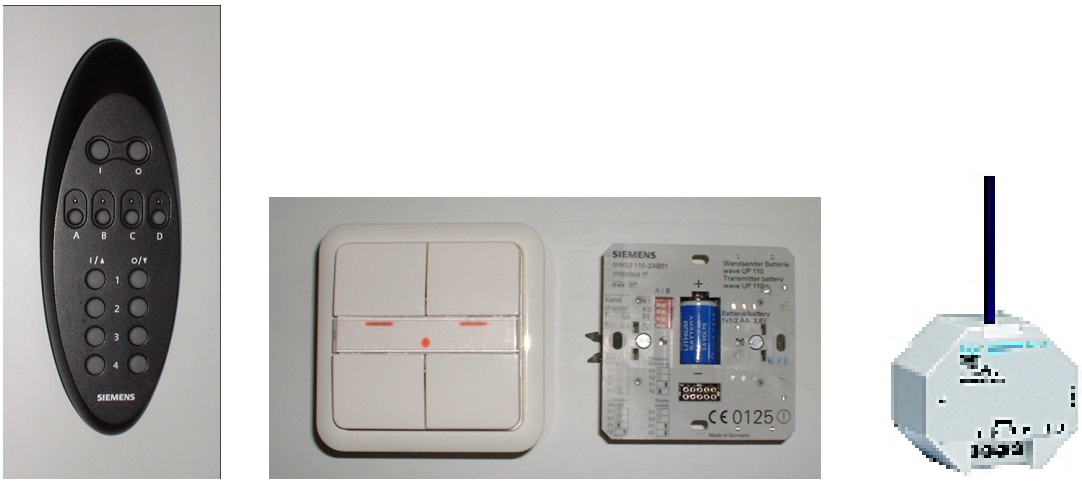
Typical hardware architecture for KNX-RF



Evaluation board bidirectional

6 Available Implementations

End devices are available from Siemens and Hager. As first company the Weinzierl Engineering GmbH offers a stack implementation for KNX-RF.

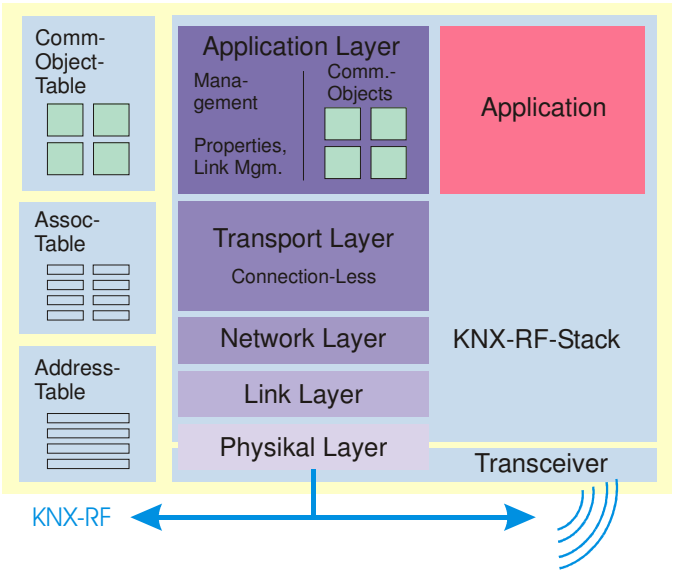


Different devices for KNX-RF (Siemens und Hager)

6.1 Stack-Implementation of Weinzierl Engineering GmbH

Building on extensive experience in developing KNX system software for twisted pair cabling und Powerline technology, Weinzierl Engineering GmbH has now developed a stack for KNX-RF as well. While the upper protocol layers have much in common with wired KNX devices, it was necessary to redefine the wireless communication in Konnex. Established modules from other device models were modified and combined with a newly developed physical layer for KNX-RF. So the new stack implementation is a combination of modules already used for wired communication and new modules for the RF communication.

As does the KNX-RF standard, our implementation differentiates between unidirectional and bidirectional devices. Unidirectional devices contain only the send function and a highly simplified communication stack. The software supports a power save mode to lengthen battery life. Because the unidirectional software has a code size of only a few kBytes, very inexpensive controllers can be used.
Our bidirectional implementation has both a sender and a receiver. Although processing of received data is time-critical due to the relatively high data rate, it is still possible to detect and correct individual bit errors during reception. Consequently, communication quality is very high even when transmission conditions are unfavourable. Bidirectional devices contain a complete communication stack that also includes the link mechanism for putting the device into operation.



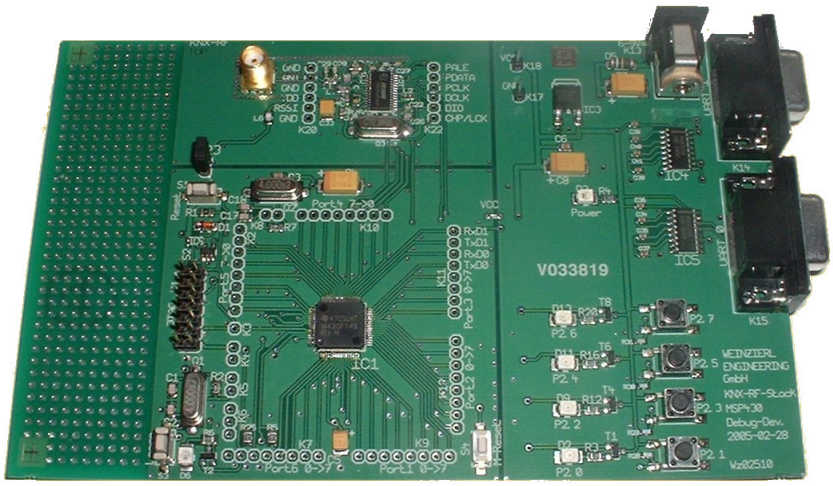
KNX-RF stack architecture

Both the unidirectional and bidirectional implementations permit integration of the application software in the controller. The stack implementation is compatible with the Konnex standard and thus with KNX devices from other manufacturers.

6.2 Hardware

For evaluation and development purpose four different hardware solutions for KNX-RF has been realized:

- KNX-RF development board (bidirectional)
- KNX-RF sensor (evaluation board unidirectional)
- KNX-RF actuator (evaluation board bidirectional)
- KNX-RF UART (evaluation board bidirectional with RS-232 interface)

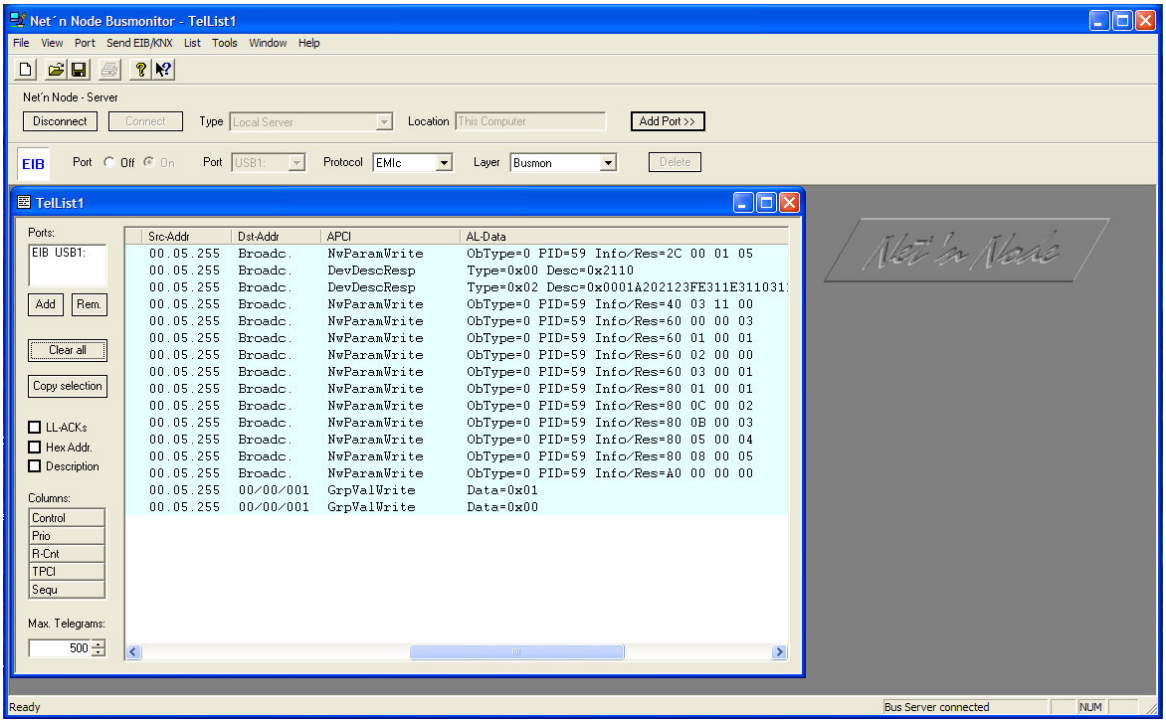


Development board for KNX-RF

Because of the requirement of very low power consumption, the microcontroller family MSP430 from Texas Intruments has been selected. For the RF interface we use components from Chipcon. With this combination it is possible to produce powerful wireless devices with low costs and low power consumption. Especially unidirectional devices can be realized at a very low cost level. Because of the modular structure of the system software it is also possible to use alternative components. The development of dedicated transceivers for KNX-RF is already planned by partners. As the implementation will be done using our stack implementation, the compatibility will be guaranteed automatically.

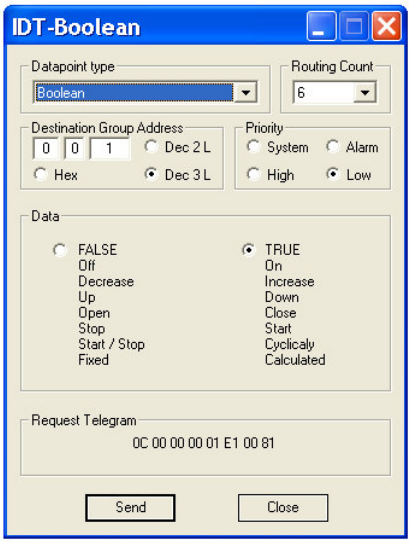
6.3 Development tools

Reliable tools are absolutely essential for effective development and for troubleshooting in existing systems. Therefore, we have extended our well-tried EIB/KNX analysis software, *Net'n Node*, for use with KNX-RF.

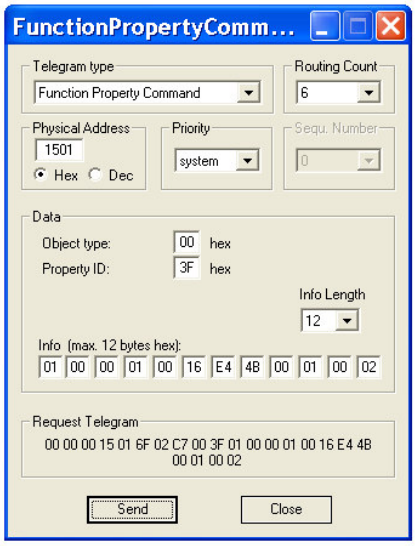


Screenshot of *Net'n Node*

Net'n Node is not only able to receive and interpret RF frames but also offers the possibility to send both runtime and management frames. For all services used by KNX-RF special input dialogs are prepared to simplify the assembling of telegrams.



Send dialog for a group telegram



Send dialog for a management telegram

The display is in cEMI format (part of the Konnex standard). A USB interface is available for KNX-RF to access the medium.

USB interface for KNX-RF

7 Conclusion

With the wireless extension KNX-RF the Konnex Association has done an essential step for the future success of the Konnex standard. Konnex-RF completes the range of the available media and enables new application areas. Using wireless communication new markets in the residential and renovation sector can be accessed.

For manufacturers it is a very important fact, that KNX-RF is available now. In addition Konnex is an open standard. It has been approved as European Norm in EN50090. The integration of KNX-RF as EN50090-5 is already in progress.

With the stack implementation and the development tools of the Weinzierl Engineering GmbH a very powerful solution is available to develop compliant devices efficiently at a low cost level.

8 Bibliography

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