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Kognitive Mediumzugangsalgorithmen für industrielle Funkanwendungen - KoMe

Cognitive Medium Access Algorithms for Industrial Wireless Systems

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Management Report

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Management Report

New concepts for the organization and control of the entire value chain along the life cycle of products require the availability of all relevant information in real time by means of networking of all instances involved in the value chain. A central component of this network, and one which will become even more important in the future, is radio communication.

The objective of this project was to utilize a radio spectrum efficiently and collision free for as many industrial radio applications as possible, allowing both the communication need and the radio channel to change dynamically while constantly meeting all requirements of availability and determinism.

The solution is based on a two-step migration strategy (Figure 1). During the first phase approaches for a central coexistence management were developed, taking into account radio communication solutions that are currently in use. As part of the analysis of existing solutions, network management solutions were examined for their applicability in the coexistence management of industrial radio systems based on the parameters found in the requirements analysis. It has been determined that none of the existing solutions are optimally suited for the application.

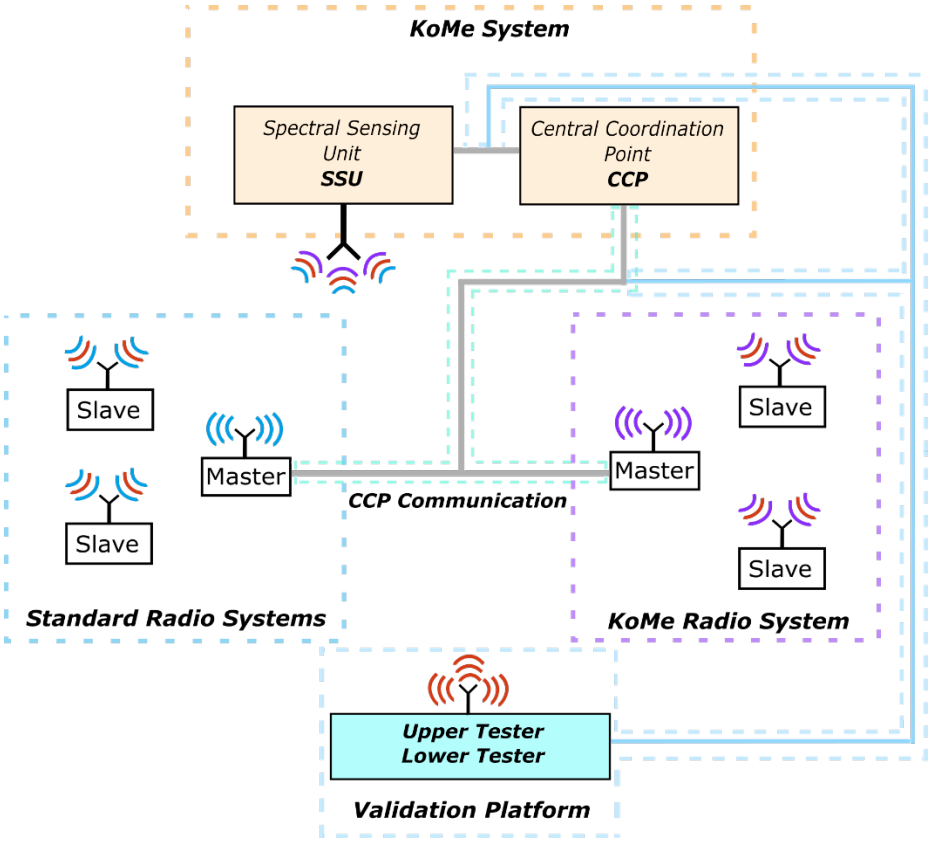

Figure 1 Solution approach

The coexistent management requires data exchange between management instances, wireless devices and systems, and spectrum sensing units. This can be served best by a central coordination point (CCP) architecture. Communication concepts such as NETCONF/YANG, OPC UA, REST and SNMP were analyzed with respect to their usability for implementing CCP communication services. Exemplary implementations disclosed problems with available software tools and frameworks. Although the basic CCP services could be successfully realized with NETCONF / YANG, REST and SNMP, the overall performance is not yet satisfactory. A stable standard is required for specifying the use of one of the investigated concepts.

For the coexistence management, new quality-of-existence parameters (QoC) were defined first. Spectral sensing is based on a previously developed NFSC classifier (neuro-fuzzy signal

classifier) which has been improved so that a significantly increased classification rate of interference systems could be achieved (Figure 2): 93 % of present and 5 % of absent WLAN signals were classified correctly.

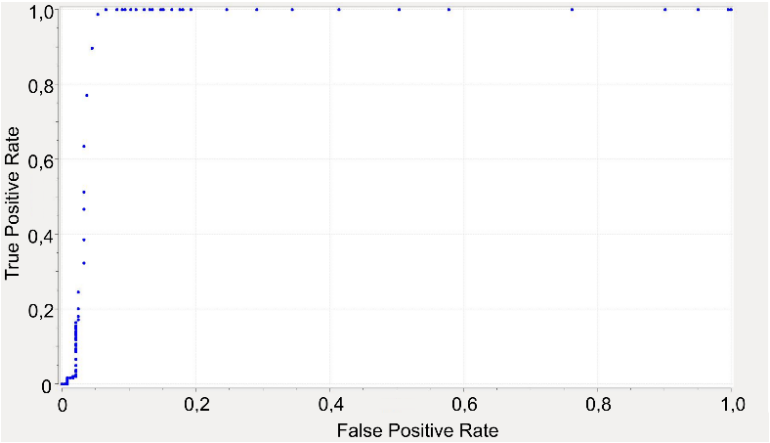

Figure 2: Receiver operation curve of the improved NFSC spectral sensing unit: WLAN signal, SNR = 10 dB

The resource allocation considered the frequency channel and the transmission power. Adjusting the transmission power defines the coverage und interference range, thus addresses the spatial dimension. The algorithm "Kassandra" was developed to optimize the distribution of both resources frequency and transmit power within a network graph (Figure 3).

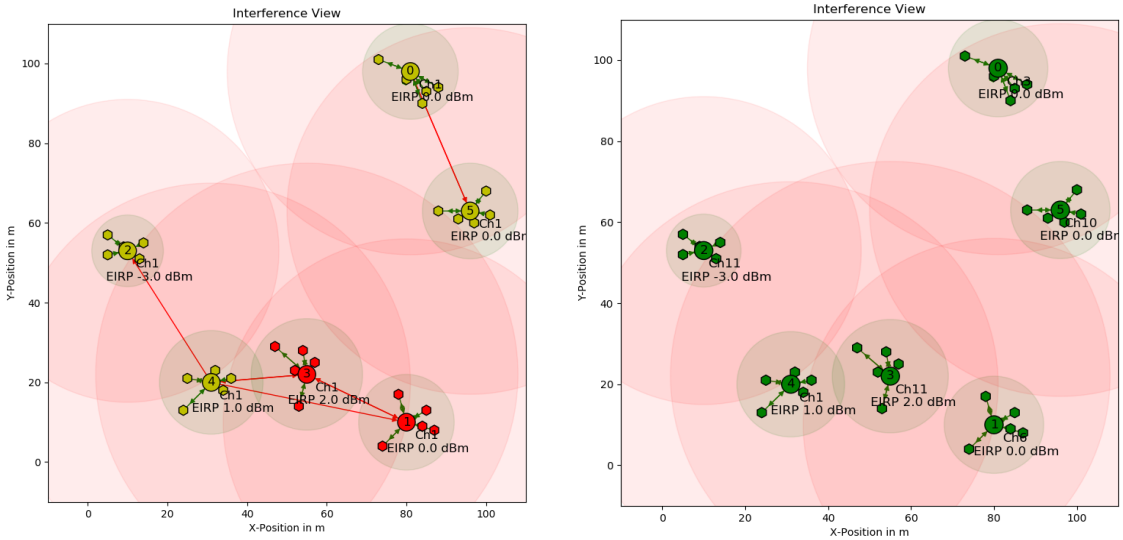

Figure 3: Representation of a typical network graph (left) with initial resource distribution; optimized resource distribution (right). Coexistence states: good (green), medium (yellow), bad (red)

The second phase comprised the development of new approaches for a system-specific media access of a new KoMe radio system and its integration into the concept of central coexistence management. The work carried out has led to new and promising concepts: Spectral shaping was addressed with the concept of ‘Generalized Frequency Division Multiplex’ (GFDM), spectral acquisition was significantly improved by the development of 'Compressive Edge Spectrum Sensing' (CESS), and the extensive evaluation of existing methods of media access allowed for the development of the new scheduling concept 'Fair Error'.

The CESS sensing method reduces the sampling rate by 85 % with no performance impairments compared to Nyquist sampling (Figure 4). Further improvements can be achieved with cooperative sensing of several sensing units.

It could be shown that optimal media access with respect to high reliability and minimal latency requires a joint parameter optimization of the physical layer, i.e. GFDM parameters, and the

MAC layer for prioritized traffic classes, i.e. real-time (RT) and non-real-time (NRT) applications (Figure 5).

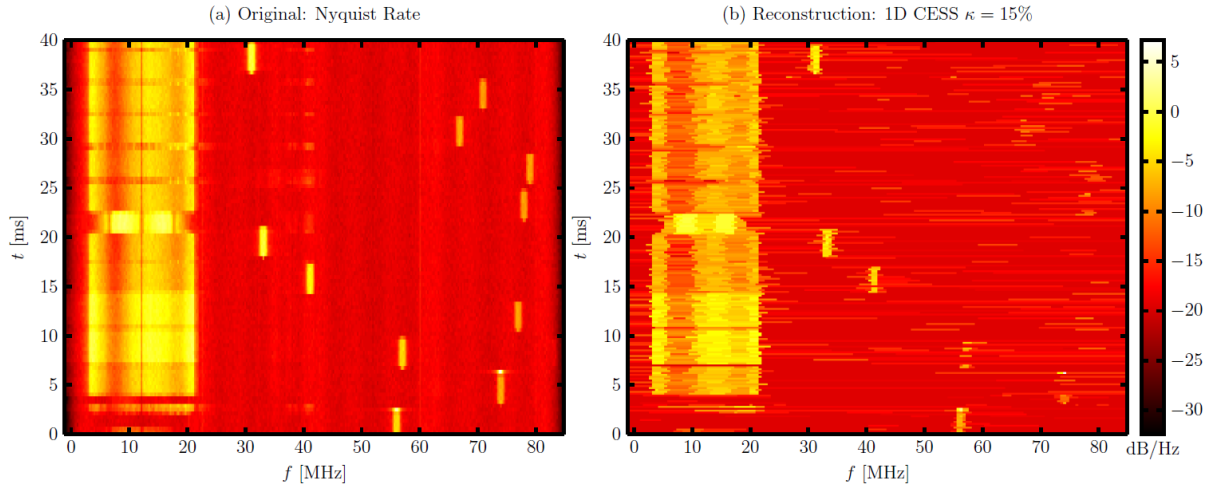

Figure 4 Computed spectrograms of WLAN and Bluetooth signals within the 2.4 GHz bands based on previous sensing: a) sampling with Nyquist rate, b) sampling with 15 % of the Nyquist rate.

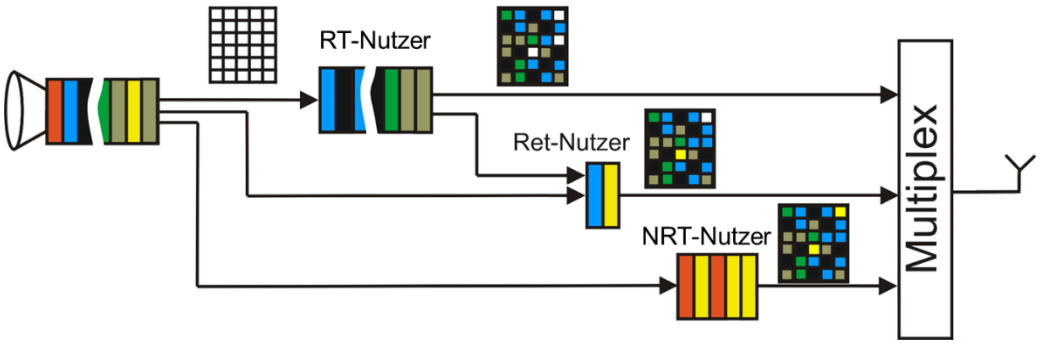

Figure 5 Schematic representation of the Fair Error Scheduler

The methodical evaluation of the developed coexistence algorithms turned out to be a challenge. The behavior of wireless devices and systems, interferers and passive environments need to be characterized appropriately, in order to be able to assess the results of the coexistence management algorithms. Therefore, a validation concept has been developed for validating the coexistence state determination, including spectrum sensing and resource allocation. These functions can be evaluated separately before testing the completed KoMe system. According to the coexistence definition of IEC 62657-1 not only the spectrum parameters are considered but also the fulfilment of the communication requirements of the wireless applications. Interference profiles have been developed based on interference sources typical for industrial production environments.

The developed validation platform considers the most relevant functions for testing coexistence management functions. It includes

- the emulation of communication requirements of automation applications that use wireless communication;
- the emulation of interferers using the specified profiles;
- the emulation of passive environmental influences between the interferer and the wireless transmitters and receivers;
- measurement and visualization functions in order to represent the results of coexistences management algorithms.

The developed KoMe solutions were exemplarily implemented on a validation platform and tested under real operating conditions with reference to their efficiency for application in machines and plants. The research results are central components of a new method for the realization of an automated coexistence management in accordance with IEC 62657-2 and IEC 62657-4.

The project was carried out by three research units and supported by nine SMBs, four large companies and one industry association in a project-accompanying committee.

The objective of the research project has been achieved.