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Distributed Iterative Decoding and Processing in Multi-Source Cooperative Networks.

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1 Current State of Art

We browse the current state of art independently for the joint network-channel code design and the FG-SPA implementation framework separately. The relation of these two topics is that the proposed FG-SPA implementation framework can be applied (among others) also for the proposed joint network-channel code design.

1.1 Joint Network Channel Code Design

The physical layer design in a general wireless physical network arose as a huge challenge recently. A pioneering work [1] showed that the information content can be temporarily mixed (network coded) within the network to increase either the overall network throughput or the system diversity. An extension of the network coding (NC) to include also the wireless environment properties (wireless network coding (WNC) a.k.a. physical layer network coding [13, 16, 20]) then brings additionally further potential performance improvement. The idea of WNC consists in decoding (providing hard decision) of a (hierarchical) function of source data streams directly in constellation space [21] and forwarding it further, thus Hierarchical Decode and Forward (HDF) strategy. Providing a hard-decision on the hierarchical stream, the classical Multiple Access Channel (MAC) region [6, 9] restrictions limiting the conventional joint-decoding based strategies does not longer limit the performance.

Since the hierarchical stream contains less information than the joint source data streams, the requested complement of this information must be delivered into the final destination by alternative paths in order to secure a reliable end to end transmission. This request is reflected e.g. by a condition that the final destination must collect enough number of equations from all paths in [21].

A proper utilization of the WNC with HDF across the network potentially takes advantage of both reduced wireless channel use and operation rates beyond the classical MAC regions. The network design contains a joint optimization over immense degrees of freedom that has to be solved. Assuming a given known network state information and a perfect time synchronization among all nodes in the network, the overall optimization can be partitioned to some interacting subtasks [28].

The available literature offers the solution either of the cases with some very specific circumstances, typically small wireless networks with fixed network information flows, or a deeper insight in some particular sub-task without taking into account the others. One can recognize two major approaches. The first one serves mainly for proving the achievability of a performance by means of the information theory tools, typically the lattice codes [10]. Some works based on this approach show very nice results, e.g.

[19]. The lattice code based models are, however, not suitable for a direct implementation. The second approach is therefore more constructive and directly implementable.

Throughout the literature, it is very common to assume a uniform information amount flowing through the relay. This allows (among others) a popular bit-wise XOR of the source data streams as the hierarchical function [4,5,16,30,31], i.e. the traditional understanding of the (wireless) network coding. The information amount is classified by means of the relay-alphabet cardinality in [26].

The consistent channel encoders design in the network is basically joint channel-wireless network coding that is able to benefit from both reduced channel use and the operational rates beyond the classical MAC region. Several works focus on the joint network-channel encoding (see e.g. [2, 11, 12]). These works are typically provided upon some graphical models [11,12]. Linearity of both network and channel coding is commonly assumed. None of these works allows to work with arbitrary channel rates and hierarchical ratios.

The joint channel-wireless network coding design appears in literature only for very simple networks with further restrictions. These restrictions are typically *symmetric* channel rates and the *uniform* information flows. For example, the authors of [16] propose both optimal and suboptimal soft metric based decoder relay design for TWRC, where the source encoders are assumed to be equal. The optimal design relies on the repeat-and accumulate codes in [16]. A similar design is proposed in [30], where the optimal design is built upon higher-order LDPC codes and the turbo codes based optimal relay decoder design is proposed in [5].

1.2 FG-SPA Implementation Framework

We can find several message representation - update rules design frameworks in literature. An example of the FG-SPA implementation improvement in case of LDPC decoding over GF(2) consists in the use of single-valued LLR values instead of the binary pmf as the message representation and the corresponding update rules can be found in [14]. An another implementation framework for the linear models with Gaussian message representation can be found in [17].

The implementation of the FG-SPA containing the mixed type message appears several time in the literature. The most straightforward method is sampling of the continuously valued message. The update rules provided upon the discretely valued sampled messages stand for a numerical integration with rectangular rule (e.g. [7, 8]). An another approach consists in the representation of the message by a Kronecker-delta function posed into maximum of the message. The update rules are (e.g. gradient methods) are proposed in [7, 8]. These update rules are built on the non-linear optimization basis. We can also mention particle method, where the message is represented by (weighted) particles (see e.g. [8] for details).

Several works (e.g. [15, 25, 27]) solve the increasing number of parameters required for the mixed-type message representation by an approximation of the mixed-type message by a properly selected well parameterizable function.

A unified framework to the message representation issue can be found in [29]. We can found several works deriving the canonical kernels and related update rules for a particular system model. As an example, the authors in [3] propose Fourier and Tikhonov message parameterization and corresponding update rules for the joint data decoding phase estimation problem.

2 Goals and Thesis Contribution

The goal of this thesis is twofold. The first goal aims with the overall channel codes construction within the network that utilizes the wireless network coding. The second goal is dedicated to the implementation issue of generic sum product algorithm that can be used for the receiver processing design. The generic nature of the sum product algorithm enables to incorporate a various number of flavours resulting from the overall network design.

The answer to the first goal is contained in the block structured layered design describing the network design for an arbitrary channel code rates and simultaneously profiting from the wireless network coding advantage. This contribution can be found also in [23]. The block structured layered design is build upon the system linearity assumption, that is linear channel codes and hierarchical functions. The channel codes can be then described by matrices (LDPC codes) that are properly composed within a global matrix in each node. Such a (block) construction indeed allows to incorporate arbitrary source rates as well as an arbitrary information flow division between the hierarchical streams (paths of the mixed information) in the network. To best of our knowledge, no such a design is available in the current state of art.

The second goal is an implementation framework for the generic sum product algorithm applicable among others also in the wireless networks. This framework should efficiently and *methodically* solve the message representation as well as an efficient implementation of the update rules upon the given message parameterization. We therefore formally describe the problem of the message representation. The solution is then introduced as the generic KLT message representation that is based on the stochastic description of the message. The message representation (approximation) obtaining is both *methodical* and *efficient*, where the optimized criteria is the MSE of the approximated message or [22]. The update rules upon the message representation for a special type of linear canonical message representation with orthogonal kernels are then proposed [24].

3 Proposed Core Principles

We point out the main ideas constituting for the main contribution of this works. The ideas can be found in [22–24].

3.1 KLT Message Representation

We assume a FG-SPA without any implementation issues with a given scheduling algorithm. The particular shape of each message depends on (1) the iteration number k and (2) a random observation input x. The true message[1] describing a variable T in a given iteration and with given observation is denoted by $\mu_{x,k}(t)$, where we assume the message to be a real valued function of argument $t \in I \subseteq \mathbb{R}$. This message can be approximated using a canonical kernel set $\{\chi_i(t)\}_i$ by

$$\mu_{x,k}(t) \approx \hat{\mu}_{x,k}(t) = \Phi(\boldsymbol{q}(x,k)) = \sum_i q_i(x,k)\chi_i(t). \quad (1)$$

The expansion coefficients $[\ldots, q_i(x,k), \ldots]$ fully describing the approximated message $\hat{\mu}_{k,x}(t) \in \hat{\mathbb{M}}$ are random.

The KLT of the process formed by the messages $\mu_{x,k}(t)$ for random iteration and observation input uses the second order statistics - the autocorrelation function $r_{xx}(s,t)$ to create an orthogonal kernel set with uncorrelated expansion coefficients and the second order moments are directly related with the residual mean square error.

The autocorrelation is function given by

$$r_{xx}(s,t) = \mathrm{E}_{x,k}\left[(\mu_{x,k}(s) - \mathrm{E}_{x,k}\left[\mu_{x,k}(s)\right])(\mu_{x,k}(t) - \mathrm{E}_{x,k}\left[\mu_{x,k}(t)\right])\right], \quad (2)$$

where $\mathrm{E}_x[\cdot]$ denotes expectation over x and $(s,t) \in I^2$. The solution of the eigenequation given by

$$\int_I r_{xx}(s,t)\chi(s)ds = \lambda\chi(t) \quad (3)$$

[1]Note that we assume a continuously valued message within this derivation, concretely the message from L_2 space. When the message is discretely valued, the proposed results can be achieved by equal steps respecting properly the discrete domain.

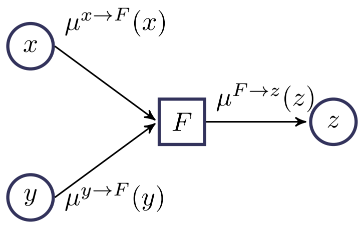

Figure 1: Visualization of the FN updated message $\mu^{F\to z}$.

produces the eigenfunctions $\{\chi_i(t)\}_i$ serving for the *orthogonal canonical kernel set* and the eigenvalues $\{\lambda_i\}_i$ serving for the importance weight of the corresponding message representation component in terms of the mean square error.

The expansion coefficients can be evaluated using the orthogonal property of the canonical kernel set by

$$q_i(x,k) = \Phi^{-1}(\mu_{x,k}(t)) = \int_I \mu_{x,k}(t)\chi_i(t)dt. \tag{4}$$

These coefficients serve for the approximated message description by (1).

The complexity (dimensionality) of the message representation can be further reduced by omitting several components $\{q_i\chi_i(t)\}$. The components with index $i > \mathcal{D}_\varepsilon$ are dropped to reduce the representation complexity. We denoted $\mathcal{D}_\varepsilon$ the number of used components (dimensionality of the message) that refers to mean square error ε. The resulting mean square error of the approximated message

$$\hat{\mu}_{x,k} = \sum_{i=0}^{\mathcal{D}_\varepsilon} q_i(x,k)\chi_i(t) \tag{5}$$

is indeed given by the term $\varepsilon = \sum_{i>\mathcal{D}_\varepsilon} \lambda_i$.

3.2 Generic Update Rules Design

We derive the FG-SPA update rules for a general Linear Canonical Message Representation (LCMR) with orthogonal canonical kernels *upon the parameterization*, that is a direct relation between the parameters of the message.

We investigate the update rules related to factor nodes (the derivation is very similar also for the update of the variable nodes). We start with a conventional FN update rule formula, [14]

$$\begin{aligned}\mu^{F\to z}(z) &= \int p(z|y,x)\mu^{x\to F}(x)\mu^{y\to F}(y)dxdy \\ &\approx \int p(z|y,x)\sum_i q_i^x\chi_i^x(x)\sum_j q_j^y\chi_j^y(y)dxdy \\ &= \sum_i\sum_j q_i^x q_j^y \int p(z|y,x)\chi_i^x(x)\chi_j^y(y)dxdy,\end{aligned}$$

where we expressed the approximated messages using the linear representation that is

$$\mu^{F\to x}(x) \approx \hat{\mu}^{F\to x}(x) = \sum_{i=1}^{\mathcal{D}(F\to x)} q_i^{F\to x}\chi_i^{F\to x}(x). \tag{6}$$

Our target is to obtain the expansion coefficients q_k^z of the approximated message $\hat{\mu}^{F\to z}(z) = \sum_k q_k^z\chi_k^z(z)$. We exploit the orthogonality of the kernels to evaluate the expansion coefficient by means of the inner product as

$$q_k^z = \langle\hat{\mu}^{F\to z}(z), \chi_k^z(z)\rangle = \sum_i\sum_j q_i^x q_j^y w_{i,j,k}^F, \tag{7}$$

where[2] $w_{i,j,k}^F = \int p(z|y,x)\chi_i^x(x)\chi_j^y(y)\chi_k^z(z)dxdzdy$ is a table determined by given kernels and a conditional probability density function (pdf) $p(z|y,x)$. The table is parameterized by i, j, k and it can be precomputed prior the processing.

We stress that (7) indeed relates the parameterization of the input and output messages.

Other update rules can be derived similarly. We refer the thesis itself or [23] for the reader interested in the FG-SPA update rules upon the message representation details.

3.3 Block Structured Layered Design

We assume a system with two sources. The joint design in the source channel encoders and the relay decoder stands for our main goal. We describe the system

$$\begin{aligned}\mathbf{c}_{AB} &= \mathbf{X}_{c,A}\mathbf{c}_A + \mathbf{X}_{c,B}\mathbf{c}_B = \mathbf{X}_{c,A}\mathbf{G}_A\mathbf{b}_A + \mathbf{X}_{c,B}\mathbf{G}_B\mathbf{b}_B &(8)\\ &= \mathbf{G}_{AB}\mathbf{b}_{AB} = \mathbf{G}_{AB}(\mathbf{X}_{b,A}\mathbf{b}_A + \mathbf{X}_{b,B}\mathbf{b}_B), &(9)\end{aligned}$$

[2]Since we assume real-valued kernel functions and real expansion coefficients, we drop the complex conjugation related to the inner product.

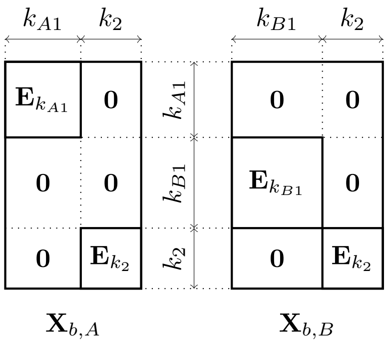

Figure 2: The dimension of hierarchical matrices in the proposed block structured layered design. Notice that the structure of the codeword hierarchical matrices is equal with dimensions $n_\star$ instead of $k_\star$.

where we assume linearity of the system, the matrices $\mathbf{X}_\star$ determine the hierarchical maps (functions) upon either codewords or data symbols and $\mathbf{G}_\star$ denotes the matrix defining the channel encoders.

We formally define our goal to have a valid network configuration. It means that $\mathbf{G}_{AB}$ must properly define the virtual hierarchical encoder, i.e. (8) must be satisfied jointly with (9) for all $\mathbf{b}_A, \mathbf{b}_B$.

Definition 3.1 (Consistent Generator Set)**.** We call a set of full-rank generator matrices $\{\mathbf{G}_{AB}, \mathbf{G}_A, \mathbf{G}_B\}$ jointly with full-rank hierarchical matrices $\{\mathbf{X}_{b,A}, \mathbf{X}_{b,B}, \mathbf{X}_{c,A}, \mathbf{X}_{c,B}\}$ satisfying

$$\mathbf{G}_{AB}\mathbf{X}_b = \begin{bmatrix} \mathbf{G}_{AB}\mathbf{X}_{b,A} & \mathbf{G}_{AB}\mathbf{X}_{b,B} \end{bmatrix} = \begin{bmatrix} \mathbf{X}_{c,A}\mathbf{G}_A & \mathbf{X}_{c,B}\mathbf{G}_B \end{bmatrix} \quad (10)$$

a *consistent generator set.*

We extend the *consistent generator set* by valid parity check matrices for decoding purposes.

Definition 3.2 (Consistent Parity Check Set)**.** The full-rank parity check matrices $\{\mathbf{H}_{AB}, \mathbf{H}_A, \mathbf{H}_B\}$ jointly with the consistent generator set are called the *consistent parity check set* if $\mathbf{H}_A$, $\mathbf{H}_B$ and $\mathbf{H}_{AB}$ are valid parity check matrices of $\mathbf{G}_A$, $\mathbf{G}_B$ and $\mathbf{G}_{AB}$.

The consistent parity check set formally states our overall goal. Among a number of approaches, we choose a joint network-channel encoding construction that produces a valid network implementation. We introduce orthogonal matrix-blocks $\mathbf{G}_{A1}$, $\mathbf{G}_{B1}$ and $\mathbf{G}_2$. One part of both individual data streams is encoded by a joint encoder $\mathbf{G_2}$ and the second part of them by separated encoders $\mathbf{G}_{A1}$ and $\mathbf{G}_{B1}$.

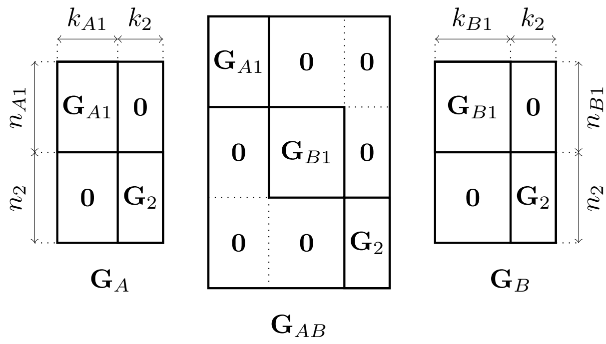

Figure 3: Diagonal block encoders composition.

Definition 3.3 (Block Structured Layered Code)**.** We assume full-rank matrices $\mathbf{G}_{A1} : n_{A1} \times k_{A1}$, $\mathbf{G}_{B1} : n_{B1} \times k_{B1}$ and $\mathbf{G}_2 : n_2 \times k_2$. If the generator matrices can be written as $\mathbf{G}_A = \text{diag}(\mathbf{G}_{A1}, \mathbf{G}_2)$, $\mathbf{G}_B = \text{diag}(\mathbf{G}_{B1}, \mathbf{G}_2)$, $\mathbf{G}_{AB} = \text{diag}(\mathbf{G}_{A1}, \mathbf{G}_{B1}, \mathbf{G}_2)$ (see Fig. 3) and the HNC matrices are in the form (see Fig. 2)

$$\mathbf{X}_{b,A} = \begin{bmatrix} \mathbf{E}_{k_{A1}} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{E}_{k_2} \end{bmatrix} \quad \text{and} \quad \mathbf{X}_{b,B} = \begin{bmatrix} \mathbf{0} & \mathbf{0} \\ \mathbf{E}_{k_{B1}} & \mathbf{0} \\ \mathbf{0} & \mathbf{E}_{k_2} \end{bmatrix}, \tag{11}$$

$$\mathbf{X}_{c,A} = \begin{bmatrix} \mathbf{E}_{n_{A1}} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{E}_{n_2} \end{bmatrix} \quad \text{and} \quad \mathbf{X}_{c,B} = \begin{bmatrix} \mathbf{0} & \mathbf{0} \\ \mathbf{E}_{n_{B1}} & \mathbf{0} \\ \mathbf{0} & \mathbf{E}_{n_2} \end{bmatrix}. \tag{12}$$

The matrices are called *block structured layered code.*

The following theorem states that the *block structured layered* code satisfies the consistency parity check conditions.

Theorem 3.1 (Block-Structured Layered Code Construction)**.** *We assume an arbitrary* block structured layered *code and denote* $\mathbf{H}_{A1} : (n_{A1} - k_{A1}) \times n_{A1}$*,* $\mathbf{H}_{B1} : (n_{B1} - k_{B1}) \times n_{B1}$ *and* $\mathbf{H}_2 : (n_2 - k_2) \times n_2$ *parity check matrices of the generator blocks* $\mathbf{G}_{A1}$*,* $\mathbf{G}_{B1}$ *and* $\mathbf{G}_2$ *in a full-rank form. Then the parity check matrices* $\mathbf{H}_A = diag(\mathbf{H}_{A1}, \mathbf{H}_2)$*,* $\mathbf{H}_B = diag(\mathbf{H}_{B1}, \mathbf{H}_2)$ *and* $\mathbf{H}_{AB} = diag(\mathbf{H}_{A1}, \mathbf{H}_{B1}, \mathbf{H}_2)$ *form a consistent parity check set.*

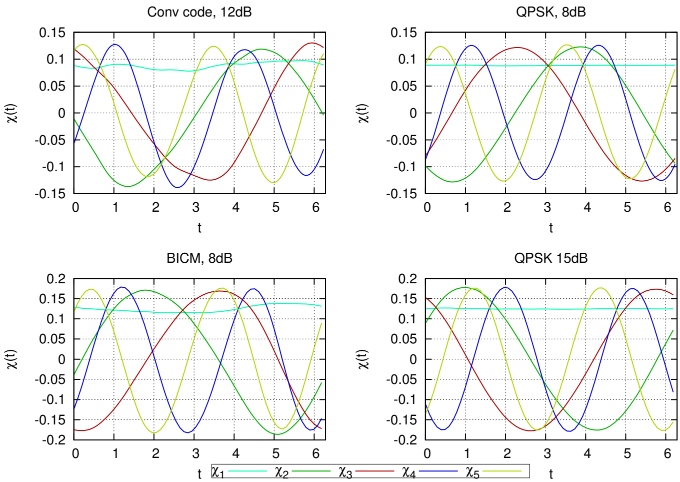

Figure 4: Shape of canonical kernel functions for different system configuration in phase space.

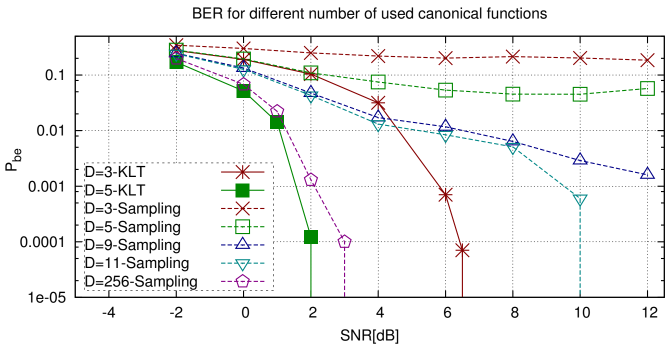

Figure 5: BER comparison of the proposed implementation framework based on the KLT approximated message with the representation by samples updated using the numerical integration with rectangular rule.

	Sampling			KLT	
	$D = 3$	$D = 11$	$D = 256$	$D = 3$	$D = 5$
Table	0	0	0	0.8	3
$+$	1.4	14.1	6746	0.7	2.8
$\times$	2.2	18.1	7640	1.7	6
$\exp(\cdot)$	0.6	5.5	2543	0	0
$\text{abs}(\cdot)$	0.2	0.8	19.7	0	0
$\Psi_{i,k}(u)$	0	0	0	0.01	0.02

Table 1: Number of symbol by symbol operations of some selected representations during the evaluation of the phase model.

4 Numerical Results

We point out some numerical results proving the usability of the proposed methods. Particularly the result of the stochastic analysis (canonical kernels for the KLT message representation) in the phase model is shown in Fig. 4. The results of the implementation framework based on the KLT message representation and its comparison with the conventional solution can be found in Fig. 5, while the corresponding complexity are shown in Tab. 1. Finally the BER simulation verifying the proposed block structured layered design is shown in Fig. 6.

5 Conclusions

The main topic of this thesis is the receiver design in a multi-source multi-node wireless network. We cope this topic from two layers. The first one is the overall network design on the channel code level, the latter consists in a direct implementation of the generic sum product algorithm that is capable to describe among others the receiver in the wireless network. One can see a clear relation between the mentioned topics, that is the overall network design properly and efficiently implemented by means of the sum product algorithm.

The sum product algorithm direct implementation was solved by the implementation framework containing the proposed generic KLT-message representation and the update rules design upon the message representation that are applicable among others to the proposed generic KLT message representation. We numerically figured out that the messages in a wide class of phase models lead to the harmonic eigenfunctions applying the KLT on their stochastic description (see Fig. 4). This proves the Fourier representation to be the best possible linear message representation in the MSE sense. We further proposed update rules design for an arbitrary linear message representation with orthogonal canonical kernels.

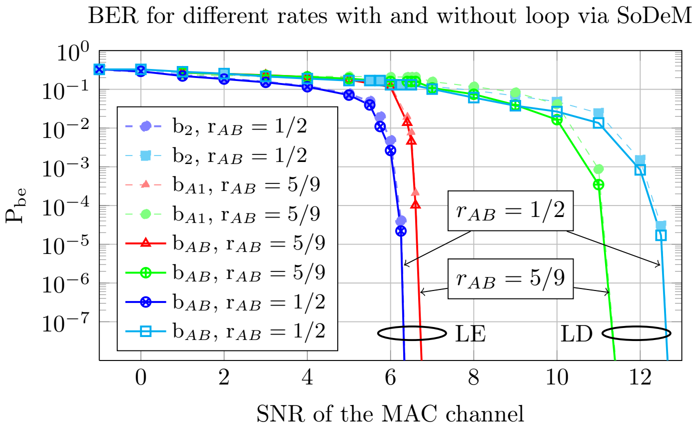

Figure 6: BER of the stream $\mathbf{b}_{AB}$ with a sub-stream for different hierarchical rates. The BER is evaluated for 1) pure decoder (no interaction between the demodulator and decoder is allowed) and 2) joint demodulator decoder with enabled interaction. The waterfall behaviour proves the framework functionality.

The assumption of the linearity and orthogonality is inherently satisfied for the KLT-message representation. The proposed update rules design jointly with the KLT-message representation therefore form a generic implementation framework applicable whenever the stochastic description of the messages is available, i.e. KLT of the random process given by the different message realizations can be evaluated. We used the Fourier representation for the proposed implementation framework verification in the given joint data detection-phase estimation system model. The proposed implementation framework that results in a highly efficient implementation (check Tab. 1 and Fig. 5) for this particular scenario.

The demand for a flexible wireless aware joint network-channel code design becomes clear after proving the wireless network coding potential (see e.g. [19]). We started with defining a robust system description. This description is based on the system linearity, that is the linear hierarchical function and the channel code. The linearity assumption is satisfied by conventional capacity achieving codes (e.g. LDPC or turbo codes). We form a Theorem 3.1 defining a block structure of the channel codes across the network. The relation of the inner block sizes (diagonal structure is assumed) determines the particular channel code rates. Arbitrary channel code rates can be adjusted. The overall decoder is basically composed from the conventional LDPC block-decoders, where the soft information exchange between the (independent) block parts can be conducted e.g.

via soft output demodulator for higher order alphabets. The performance for different metrics evaluated in the soft output demodulator and corresponding decoder structure is evaluated in a particular system model (check Fig. 6). These results proves the waterfall behaviour indicating a proper decoder implementation.

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Summary

The wireless network coding [13, 16, 20, 26] (wireless extension of the network coding [1, 32]) was shown to have a potential to significantly improve the performance in the wireless networks against the conventional networks based on independent (or interfering) point to point channels directed by higher layers. The whole network must be designed jointly to take advantages from the wireless network coding. This thesis aims with (1) the global design of the channel encoders and corresponding decoders among all nodes within the wireless network and (2) the receiving processing of a particular node in the wireless communication network.

The solution of the global channel coders design across the network is called the *block structure layered design* [23] allowing to incorporate arbitrary particular channel code rates. The design is based on a *linear* description of the wireless network containing hierarchical maps (network coding) and channel coding. The design combines already known approach suited just for symmetric channel code rates [16] properly utilizing advances of the network coding paradigm [32] in wireless extension. This principle is mixed with traditional joint decoding such that the desired code rates and relay information flows are achieved in average over whole codeword. This mixture results in the *block diagonal* structure using the proposed linear system description. We numerically verify the proposed design in a particular wireless network.

The decoding procedures are addressed to sum product algorithm on factor graphs [14, 18] within this work. This generic tool enables a construction of the receiver processing for a general class of scenarios including the wireless networks. The thesis aims with a direct implementation of the sum product algorithm that is applied in the receiver within the wireless networks. Our endeavour results in a generic implementation framework of the sum-product algorithm [22, 24] that is applicable in a wide class of scenarios including the receiver processing in the wireless networks. The framework is based on the proposed KLT message representation. The KLT message representation is capable to methodically describe an arbitrary continuous message in the FG-SPA, whenever the KLT of the random process formed by random message realizations can be evaluated. We further derive the update rules upon linear message representations with orthogonal kernels. The KLT message representation satisfies both the linearity and the orthogonality of the kernels and therefore the proposed update rules design is applicable also for the KLT message representation. The KLT message representation jointly with the update rules design therefore form the generic *FG-SPA implementation framework*. The proposed implementation framework is verified in a particular scenario (a receiver aiming with joint phase estimation data detection) and compared with a conventional solution.

Anotace

Sdružené kódování v bezdrátových sítích na fyzické vrstvě (wireless network coding [13, 16, 20, 26]) představuje potenciál pro komunikaci s lepšími vlastnostmi než tradiční přístup řízení fyzické vrstvy vyššími vrstvami (OSI model). Tyto vlastnosti lze dosáhnout, pokud je návrh fyzické vrstvy proveden globálně (sdružené kanálové a síťové kódování přes celou bezdrátovou síť). Klíčovými vlastnostmi sítě jsou především propustnost informace pro daný výkon a spolehlivost správného dekódování v určeném uzlu (destinaci). Hlavním tématem práce jsou především (1) globální návrh sdruženého síťového a kanálováho kódování v bezdrátové síti a (2) návrh algoritmu a jeho implementace pro přijímač.

Řešení globálního návrhu kódování je pojmenováno *block structure layered design* [23]. Toto řešení umožňuje komunikaci pro libovolné kódové poměry a informační toky v síti. Žádné takové řešení není v současné literatuře zatím popsáno. Navrhované řešení stojí na linárním popisu systému, který svazuje kanálové a síťové kódování pro daný informační tok v daném uzlu. Samotné řešení poté kombinuje sdružené dekódování a speciální případ dekódování využívající síťové paradigma (network coding paradigm [32]). Řešení využívající síťového paradigmatu jsou zatím popsány pouze pro speciální případy, kde jsou kanálové kodéry v síti stejné [16]. Kombinace uvedených principů vede na blokovou (blokově-diagonální) strukturu matic popisující kanálové kodéry pro navržený lineární popis sítě. Návrh je ověřen numerickou simulací v konkrétní síti.

Dekódování v této práci je prováděno pomocí sum product algoritmu na faktorových grafech [14, 18]. Tento algoritmus vyniká svou obecností. Je schopen popsat libovolný systém pomocí jeho vnitřní struktury. Globální řešení je poté faktorizováno pomocí vnitřní struktury systému s násobně lepší efektivitou. Obecnost tohoto algoritmu umožňuje jeho použití pro návrh přijímače v bezdrátové síti správně respektujícího globální návrh systému. Tato práce se zabývá přímou implemementací sum product algoritmu, který může být použit mimo jiné v přijímači v bezdrátové síti. Výsledkem práce je implementační framework sum product algoritmu [22, 24]. Výsledný implementační framework obsahuje navrženou KLT representaci zpráv [22] systematicky řešící reprezentaci spojitých zpráv. Další částí implementačního frameworku je generický návrh pravidel pro výpočet zpráv (update rules) nad reprezentací zpráv. Navržená pravidla lze aplikovat na libovolnou lineární reprezentaci zpráv s ortogonálním bázovým rozkladem. Vzhledem k tomu, že důsledkem KLT vede navržená reprezentace zpráv na lineární reprezentaci zpráv s ortogonálním bázovým rozkladem, navžená KLT reprezentace zpráv s navrženýmy pravidly tvoří implementační framework pro sum product algoritmus aplikovaný v libovolném systému. Implementační framework je ověřen na aplikaci sdruženého dekodéru a fázového estimátoru a porovnán s tradičním řešením.

Publications Related with the PhD Thesis

Journals Ranked by Impact

- Pavel Prochazka and Jan Sykora. Karhunen-Loève based reduced-complexity representation of the mixed-density messages in SPA on Factor Graph and its impact on BER. *EURASIP J. on Wireless Comm. and Netw.*, 2010:11, December 2010.

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Other Conferences

- Pavel Prochazka and Jan Sykora. Generic efficient FG-SPA implementation framework based on the best linear canonical message representation in MSE sense. *European Wireless 2013*, 2013.
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Other Publications

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- Jan Sykora and Pavel Prochazka. Performance evaluation of the factor graph CPM phase discriminator decoder with canonical messages and modulo mean updates. In *Proc. IEEE Asia-Pacific Conf. on Communications (APCC)*, pages 1–5, Tokyo, Japan, October 2008. **PP – 30%**

Other Conferences

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Impact of the Authors Publications

Citations