Research Paper Presentation

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Title and Author

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Estimation of Observation Error Probability in Wireless Sensor Networks

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Abstract

- Propose for a parallel wireless sensor network (WSN) model
- A decoding technique that well exploits the knowledge of the sensing data to be transmitted from each sensor to the fusion center (FC).
- Algorithm to estimate the observation error probabilities
- The convergence of the algorithm is also evaluated with comparison of bit-error-rate (BER)

System Model

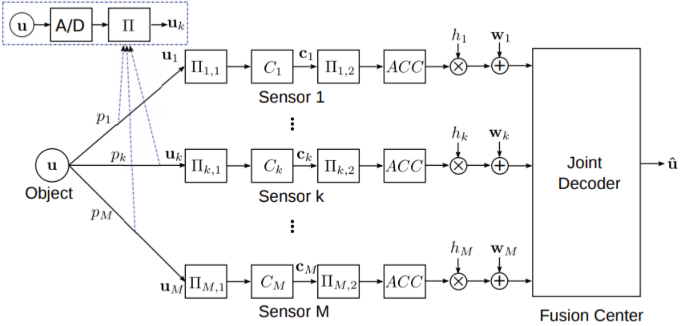

Figure: Structure of proposed system model

System Model

1. *A/D converter* :
   - convert analog signal to digital bit sequence
2. *Interleaver* (Π) :
   - Intermixes signal thus converting bunch error to random error
3. *Channel encoder* (C_k) :
   - used to detect error and correct some of them
   - Introduce bit sequence which help in overcoming effect of white noise
4. *ACC* :
   - Doped Accumulator (ACC) takes XOR of signal with some bit sequence
5. *channel coefficient* :
   - Scale a signal
6. *White gaussion noise* :
   - basic model to mimic effect of random process that occur in nature

System Model

- Error corrupted binary sequence u_k , $k \in \{1, \ldots, M\}$ obtained after interleaver Π followed from A/D converter.
- p_k be the bit flipping probability for the sensor k.
- signal u_k is interleaved by $\Pi_{\mathrm{K},1}$
- Then encoded by channel encoder C_k
- encoded bit sequence c_k interleaved by the interleaver $\Pi_{\mathrm{k},2}$ and doped-accumulated by ACC
- then it modulated by BPSK thus gives s_k
- transmitted to the FC over independent static AWGN channels
- finally we get bit sequence y_k

$$y_k = h_k \times s_k + w_k \tag{1}$$

h_k is channel coefficient and w_k is zero mean Gaussian noise

Decoding

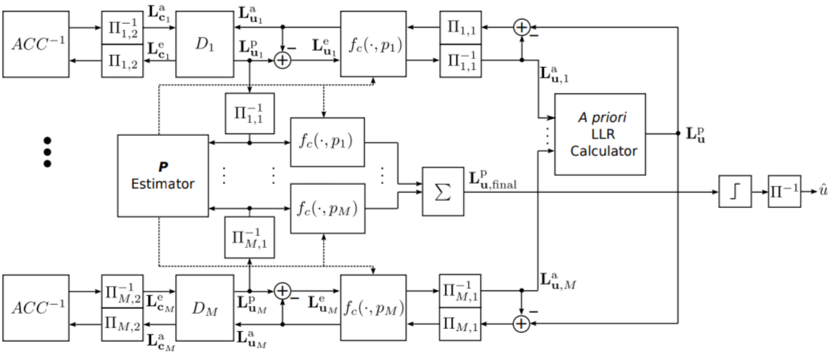

Figure: Proposed decoding strategy for a parallel sensor network

Decoding

Decoding consist of three parts :

1. Local iteration
   - In LI extrinsic LLR exchange between decoder D_k and doped accumulator ACC^{-1} takes place
   - takes *priori* LLR $\mathrm{L}_{\mathrm{u}}^{a}$ and gives back *posteriori* LLR L_{uk}^{p} after performing decoding and ACC^{-1}
2. P estimator
   - then a *posteriori* LLR L_{uk}^{p} containing some error are feed to P estimator to calculate p_k
   - Value of p_k are used by $f_c(\cdot, p_k)$ function
3. Global iteration
   - Extrinsic LLR exchange between Decoders

LI and *GI* are performed until no more relevant gain can be achieved in a final *posteriori* LLR $\mathrm{L}_{\mathrm{u,final}}^{p}$

P Estimation

- $j = i + 1$ if $i = 1 \ldots M - 1$ and $j = 1$ if $i = M$
- N : number of the LLR pairs with their absolute values larger than a given threshold T

$$\hat{q}_{ij} = \frac{1}{N} \sum_{1}^{N} \frac{\exp(\mathrm{L}_{\mathrm{u}i}^{p}) + \exp(\mathrm{L}_{\mathrm{u}j}^{p})}{\left[1 + \exp\left(\mathrm{L}_{\mathrm{u}i}^{p}\right)\right] \cdot \left[1 + \exp(\mathrm{L}_{\mathrm{uj}}^{p})\right]} \tag{2}$$

Let I be identity matrix of size M and J be defined in (4) of size M

$$\hat{\mathrm{q}} = \left[(\mathrm{I} + \mathrm{J}) - 2 \cdot \operatorname{diag}\left(\hat{\mathrm{P}}\right) \cdot \mathrm{J}\right] \cdot \hat{\mathrm{P}} \tag{3}$$

Here $\hat{\mathrm{P}} = [\hat{p}_1, \hat{p}_2, \ldots, \hat{p}_M]^{\mathrm{T}}$ and $\hat{\mathrm{q}} = [\hat{q}_{12}, \hat{q}_{23}, \ldots, \hat{q}_{M1}]^{\mathrm{T}}$
The $\operatorname{diag}(\cdot)$ is the operator that forms a diagonal matrix from its argument vector.

P Estimation

$$J = \begin{bmatrix} 0 & 1 & 0 & 0 & \dots 0 \\ 0 & 0 & 1 & 0 & \dots 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & 0 & 0 & 0 & \dots 0 \end{bmatrix} \tag{4}$$

Objective : to find $\hat{P} \succcurlyeq 0$ which minimize $\|A\hat{P} - \hat{q}\|^2$
where, $A = \left[(I + J) - 2 \cdot \text{diag}\left(\hat{P}\right) \cdot J\right]$
We solve this using iterative algorithm summerized in Alogorithm 1.In this algorithm, we use the standard Non negative Least Squares *(lsqnonneg)* algorithm

Algorithm 1: P Estimator

Input: $\hat{\mathrm{q}}$, ϵ, Pre-defined maximum iterations IT_m

Output: $\hat{\mathrm{P}} \succcurlyeq 0$ such that $\|\mathrm{A}\hat{\mathrm{P}} - \hat{\mathrm{q}}\|^2$ is minimized

Initialization: $\hat{\mathrm{P}}^{(0)} = 0$, Calculate A and $\Delta(0) = \|\mathrm{A}\hat{\mathrm{P}}^{(0)} - \hat{\mathrm{q}}\|^2$;

for $l = 1$ *to* IT_m **do**

  Calculate $\hat{\mathrm{P}}^{(\mathrm{l})}$ by using *lsqnonneg* algorithm;

  Update $\mathrm{A} = \left[(\mathrm{I} + \mathrm{J}) - 2 \cdot \mathrm{diag}\left(\hat{\mathrm{P}}^{(\mathrm{l})}\right) \cdot \mathrm{J}\right]$;

  $\Delta(\mathrm{l}) = \|\mathrm{A}\hat{\mathrm{P}}^{(\mathrm{l})} - \hat{\mathrm{q}}\|^2$;

  if $\Delta(\mathrm{l}) > \Delta(\mathrm{l} - 1)$ **then**

    Exit For;

  end

  if $\|\hat{\mathrm{P}}^{(\mathrm{l})} - \hat{\mathrm{P}}^{(\mathrm{l}-1)}\|^2 \leq \epsilon$ **then**

    Exit For;

  end

end

$\hat{\mathrm{P}} = \hat{\mathrm{P}}^{(\mathrm{l})}$;

Significance

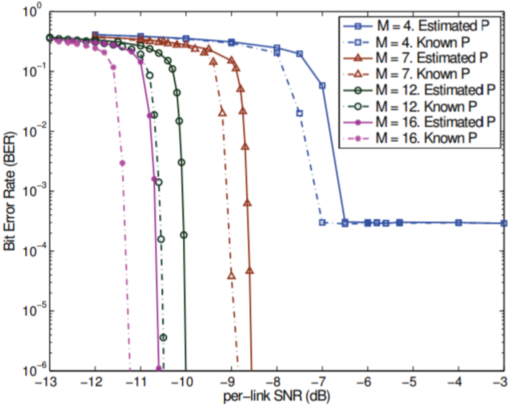

Figure is drawn for

- $T = 2$
- $\epsilon = 10^{-6}$
- Iteration time $IT_M = 20$

using estimated $\hat{P}$ can cause roughly 0.3to0.5 dB loss in per-link SNR compared to actual $\hat{P}$

Our model gives $2 - 3$ dB improvement than earlier models