Cooperative Turbo-Coded Diversity

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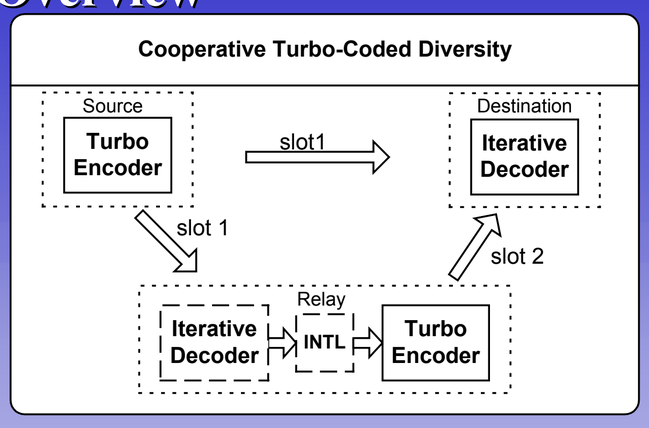
Overview



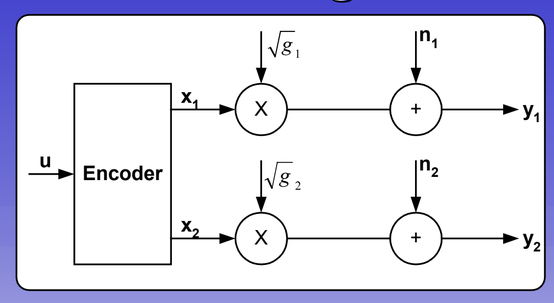
Objective:
Utilize relay with a distributed turbo encoding of source's message for cooperative diversity on the block fading channel.

Assumptions:
- half-duplex terminals; use time slotting for the orthogonality of transmission.
- source-destination and relay-destination links are statistically equal with quasi-static, independent, non-selective Rayleigh fading.
- Source-relay link is "reliable".

Related work

- Madsen derived the capacity for relay networks with half-duplex relay terminals
- Sendonaris et al introduced the "user cooperation diversity".
- Laneman and Wornell studied the orthogonality between source and relays.
- Laneman et al analyzed the performance of several cooperation strategies.
- Zhao and Valenti proposed "distributed turbo codes" to gain the performance promised in these works.
- Knopp and Humblet studied convolutional codes which maximizes the diversity gain.
- Stefanov and Erkip proposed a convolutional coding scheme which utilizes the ideas in Knopp et al.
- Zhang and Duman developed an iterative decoding scheme which operates over the superposition of transmitted blocks jointly.

Block-Fading channel



- The channel can be modeled in complex baseband equivalent, discrete time form as:

$$y[n] = \sqrt{g_k}\, x[n] + z[n]$$

where $y[n]$ is the received signal, $x[n]$ is the transmitted signal, $z[n]$ is the additive receiver noise and g_k captures the effects of the multipath fading.

- The transmitted signal energy is constrained by:

$$E\left[\left|x_i\right|^2\right] \le RE_b$$

where R is in bits/modulator symbol

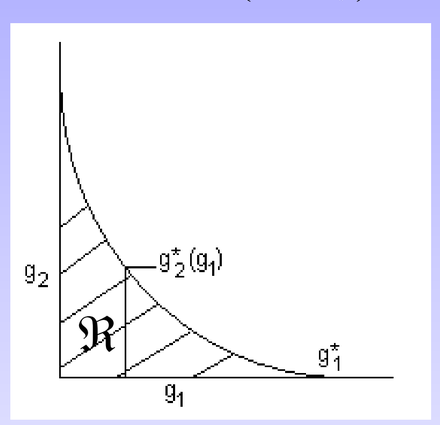
- $z[n]$ is zero-mean complex Gaussian random with variance $N_{0,}$ g_k are independent and exponentially distributed with unit variance.

Gaussian inputs, repetition

- $I\left(\underline{X};\underline{Y}\,|\,\underline{g}\right) = \frac{1}{2}\log_2\left(1+\left(g_1+g_2\right)\frac{RE_b}{N_0}\right) bits/symbol$
- Outage event: $R > I\left(\underline{X};\underline{Y}\,|\,\underline{g}\right)$
- $P_{out} = P\left[g_1+g_2 \le \frac{2^{2R}-1}{R\,E_b/N_0} = \gamma_{GR}\right]$
- g_1+g_2 is chi-square with four degrees of freedom
- $P_{out} = 1-e^{-\gamma_{GR}} - \gamma_{GR}e^{-\gamma_{GR}}$

Gaussian inputs, non-repetition

- $I\left(\underline{X};\underline{Y}\,|\,\underline{g}\right) = \frac{1}{2}\log_2\left(1+g_1\frac{RE_b}{N_0}\right)+\frac{1}{2}\log_2\left(1+g_2\frac{RE_b}{N_0}\right) bits/symbol$



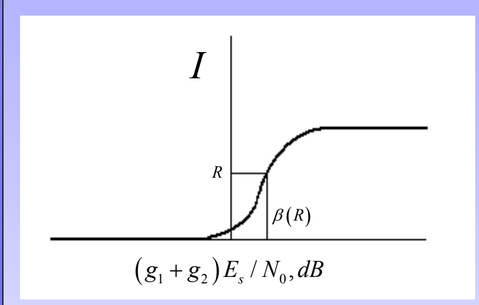
$$g_1^* = \frac{2^{2R}-1}{R\,E_b/N_0}$$

- $P_{out} = \iint_{\mathbb{R}} f(g_1) f(g_2)\, dg_1 dg_2$

$$= \int_0^{g_1^*} e^{-g_1}\left(1-e^{-g_2^*(g_1)}\right) dg_1$$

QPSK inputs, repetition

- $I\left(\underline{X};\underline{Y}\,|\,\underline{g}\right) = \int_y f\left(y\,|\,S_0,\underline{g}\right)\log_2\left(\frac{f\left(y\,|\,S_0,\underline{g}\right)}{\frac{1}{4}\sum_{S_i} f\left(y\,|\,S_i,\underline{g}\right)}\right) dy$

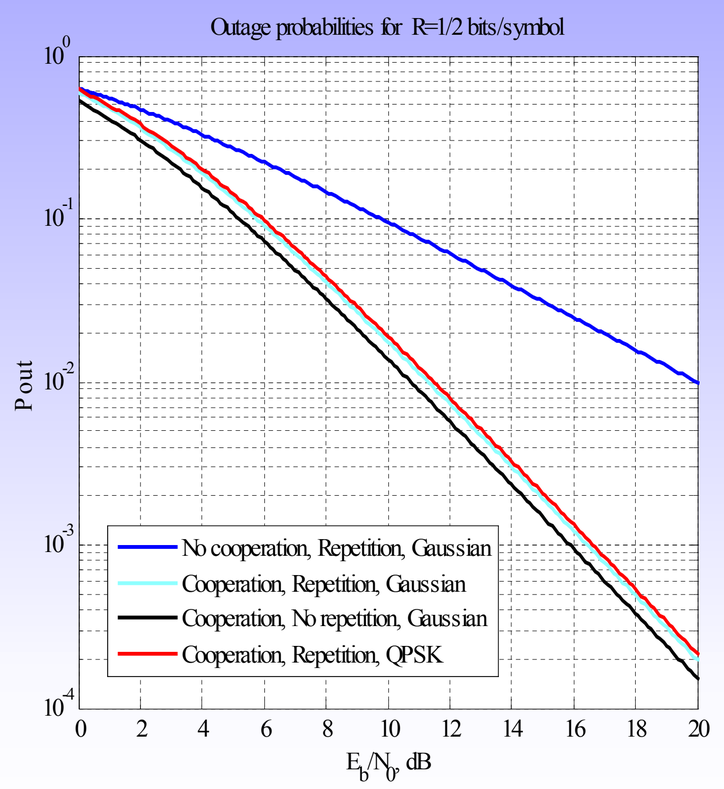


Outage event:

$R > I\left(\underline{X};\underline{Y}\,|\,\underline{g}\right)$

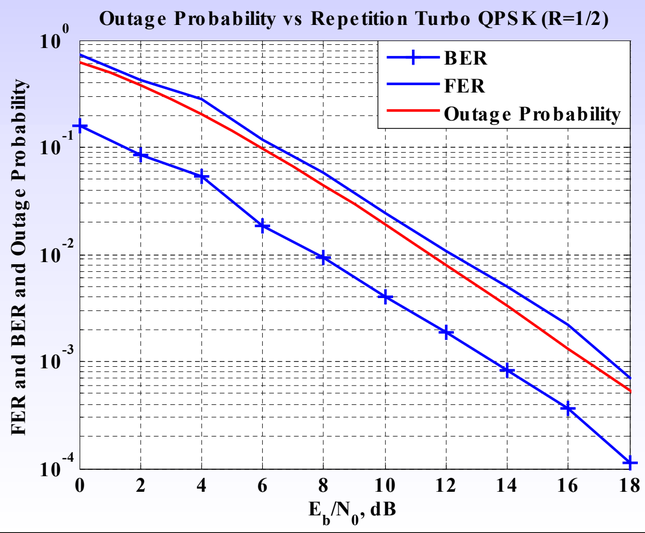
- $P_{out} = P\left[g_1+g_2 < \frac{\beta(R)}{R\,E_b/N_0} = \gamma_{QPSK}\right]$
- $P_{out} = 1-e^{-\gamma_{QPSK}} - \gamma_{QPSK}e^{-\gamma_{QPSK}}$

Outage Probability Summary



Repetition-Turbo Performance

- Turbo encoders with alternating parities punctured at the source and the relay.
- UMTS code generator (1,15/13) and interleaver for message length K=640 bits.
- QPSK modulation with R=1/2 bits/symbol
- Maximal Ratio Combining (MRC) with perfect knowledge of fading coefficients at the destination.
- 100 frame errors for every E_b/N_0 value



Concluding Remarks

- Proposed repetition turbo method performs within 0.5-1 dB of outage limit for single relay scenario.
- Repetition turbo outperforms "distributed turbo code" by more than 1 dB.
- Repetition turbo outperforms the convolutional scheme proposed in Sendonaris et al by more than 1.5 dB for a frame length of 640 bits
- Combining the channel measurements by MRC prior to iterative turbo decoding gives the best performance.
- Repetition turbo provides a stronger source-relay link.
- Relay Decoding Options:
  - Turbo decoding provides strongest source-relay link
  - Simpler is merely extracting the uncoded systematic bits