Embedding prioritized data using unequal error protection (Lizhong Zheng)

FLoWS

ACHIEVEMENT DESCRIPTION

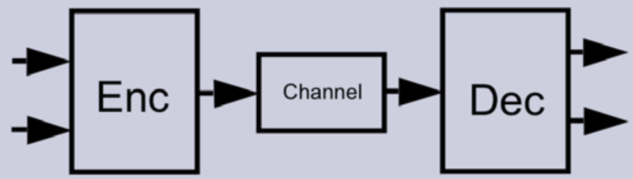
STATUS QUO

- *Physical links are viewed as equally reliable bit pipes.*
- *High priority control messages are sent over separated channels.*
- *No performance limits on UEP*

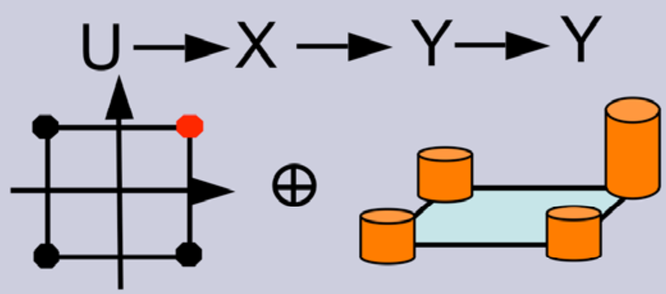
NEW INSIGHTS

Embedding key messages over UEP: performance analysis by information geometry

MAIN RESULT:



HOW IT WORKS:



- **Reduce UEP to degraded BC network**
- **Embed high priority message**

ASSUMPTIONS AND LIMITATIONS:

- **Error prob. measured in exponents**
- **Limited analytical solutions**

END-OF-PHASE GOAL

- Joint Source-Channel coding with layered codes
- Feedbacks and two-way channels
- Data driven network controls, Layering and QoS as interface

COMMUNITY CHALLENGE

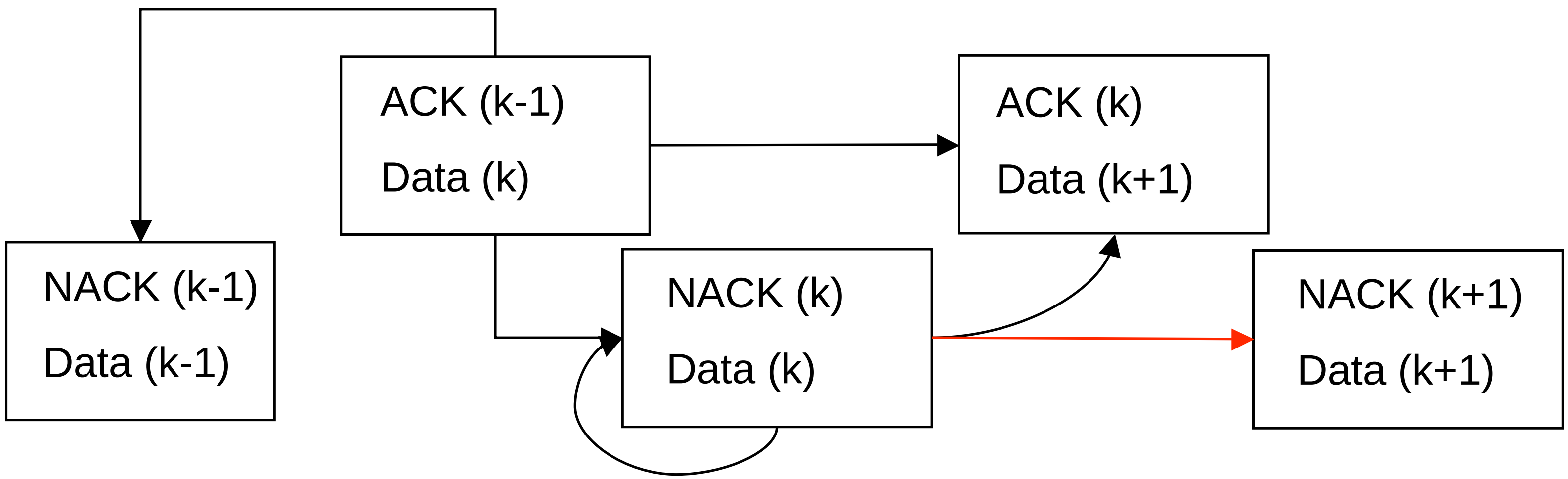
New protocols required to indicate, process, fuse, and prioritize heterogeneous data transmissions over networks

Embedding control messages/significant data with UEP

INFORMATION PROCESSING TECHNOLOGY OFFICE

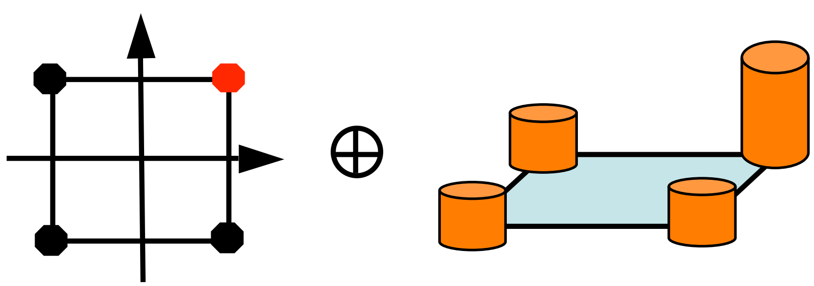
Motivating Example: Yamamoto-Ito Scheme

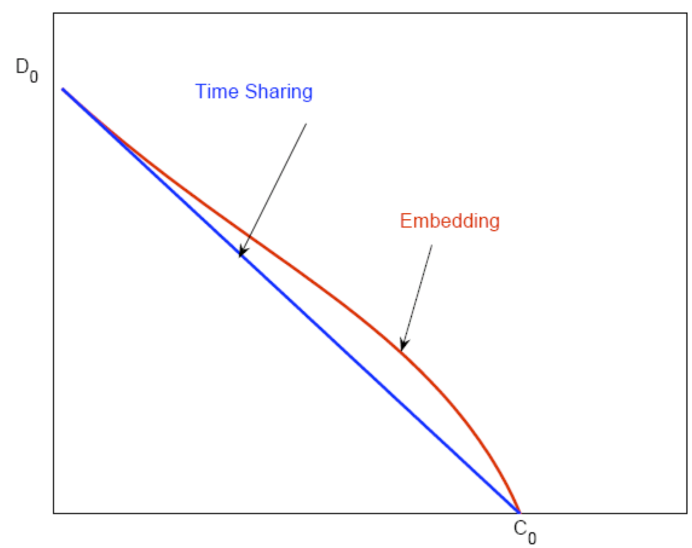
- Burnashev exponent with Yamamoto-Ito schemes with 2 phases:
  - Data communication at full capacity
  - Confirm with binary ACK/NACK with high reliability
- Encode ACK/NACK with new data
  - Both Data and ACK/NACK occupy the entire block
  - Synchronizing sequential transmission



Embedding ACK/NACK

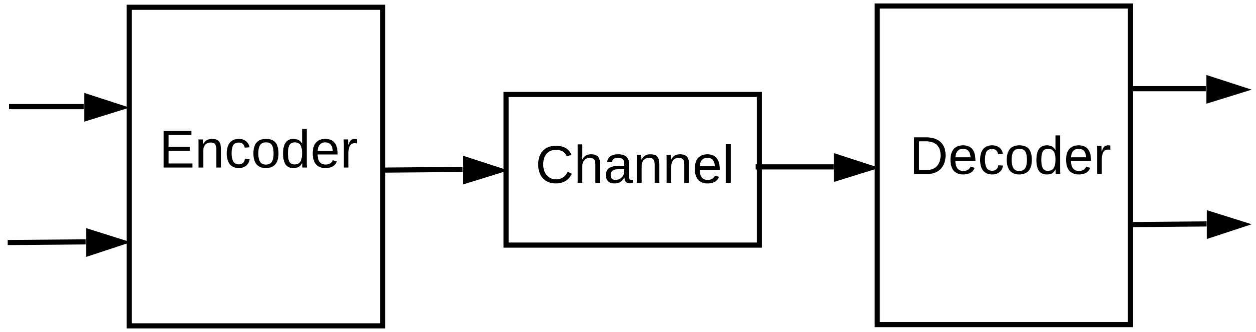
- Special case: embedding 2 bits over QPSK data symbols
- Performance metric for hierarchical error protections:
  - Throughput of data + Reliability of control
- Tradeoff between rate and reliability: controlling the distribution of the data codes
- Strictly out-perform is surprising: better than 2 bit repetition over QPSK





Control and Data Side-by-Side

- The feedback context is not important
  - Performance measured by large data and reliable control
  - Time sharing/ orthogonal resource allocation between data and control
- Layered codes with UEP



- Studied in CS under the name “priority coding”
- Systematic design approach requires error exponents

UEP and Broadcasting Channel

- UEP can be thought as board casting

$$U \xrightarrow{\Phi} X \xrightarrow{W} Y$$

- Optimization problem easy to write, difficult to solve

$$I(P_U, \Phi \circ V_1) > R_1 \qquad D(V_1||W|P_x) \leq E_1$$

For all V

$$I(X; V_2|U) > R_2 \qquad D(V_2||W|P_x) \leq E_2$$

- Many other network information theory results look similar

The Very Noisy Approximation

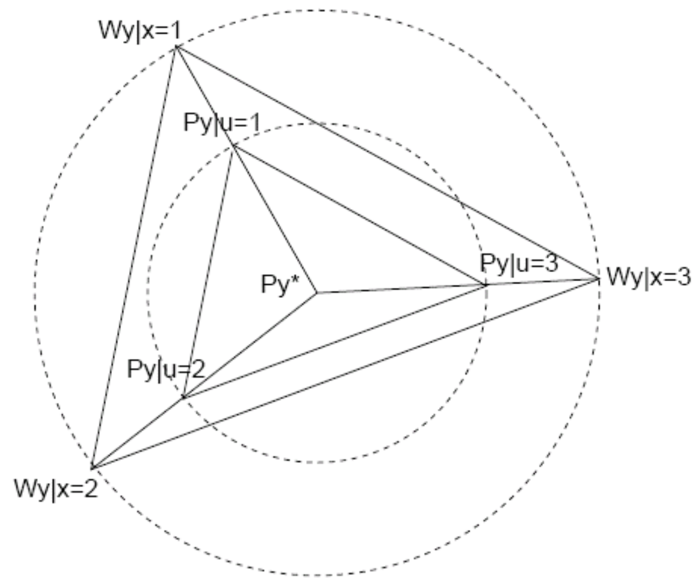
- Definition ***very noisy*** :distributions involved in divergence optimization are close
  - Local approximation of distribution manifold
  - Euclidean approximation of information geometry
  - Normal approximation of the distribution of information quantity
  - Quadratic approximation of divergence
- Examples of very noisy cases
  - Very noisy channel codes
  - Source coding for nearly uniform source
  - Very low rate quantization
  - Good approximation to general cases

new canonical example?

UEP for Very Noisy Channel

- If the given channel has capacity C ~ 0

  Optimal input (U,X)
  - Px is capacity achieving
  - Py|u proportional scaling



- Achievable region

$$\frac{R_1}{(\sqrt{C}-\sqrt{E_1})^2}+\frac{R_2}{(\sqrt{C}-\sqrt{E_2})^2}\leq 1$$

Comparison and Insights

- Embedded UEP

$$\frac{R_1}{(\sqrt{C}-\sqrt{E_1})^2}+\frac{R_2}{(\sqrt{C}-\sqrt{E_2})^2}\leq 1$$

- Time sharing

$$\frac{R_1}{\left(\sqrt{C}-\sqrt{\frac{E_1}{\alpha}}\right)^2}+\frac{R_2}{\left(\sqrt{C}-\sqrt{\frac{E_2}{1-\alpha}}\right)^2}\leq 1$$

- Insights:
  - Very noisy is very nice
  - Combining control and data allows global optimization
  - Networking based on imperfect controls
  - Geometric approach for error exponent

Achievement report

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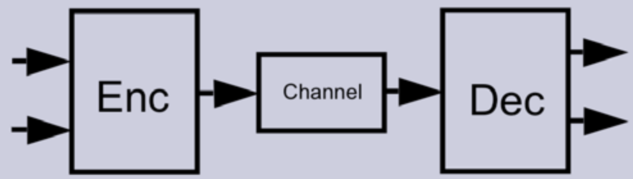

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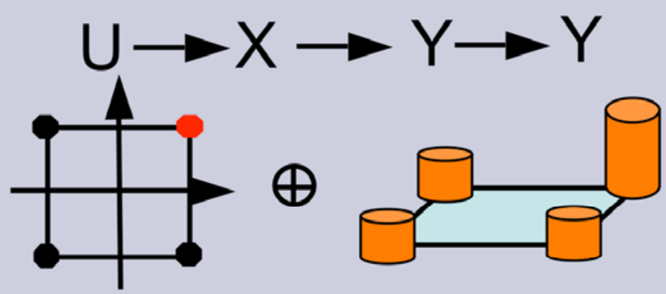

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