International Chair IoTAD-CEO

Chair holder: Tadashi Matsumoto

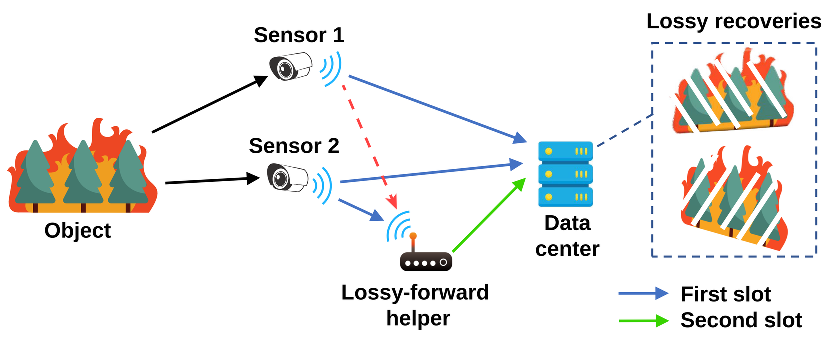
1. Project scientific objectives

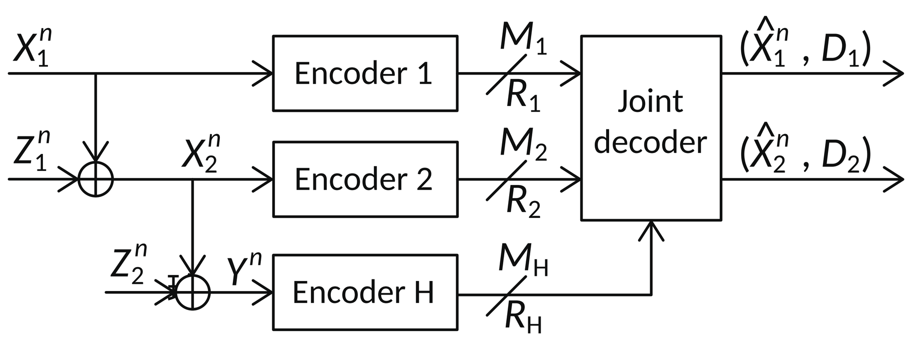
- Consider **Multi-Terminal Lossy Source coding** with applications to Beyond 5G and 6G Wireless Communication Systems
- Advance research on **information theory** and **coding**, by considering **complex communication scenarios** (relaying, multiple-access fading channels, etc.)
- Address different **communication objectives**: distortion (conventional source reconstruction), and/or correct decision-making

2. Cooperative lossy communication over fading MAC channel

Model

- Reconstruction of two binary sources with a **helper**: $X_2 = X_1 \oplus Z_1$, $Y = X_2 \oplus Z_2$
- Transmission over block **Rayleigh MAC fading channels**
- The two sources are jointly reconstructed



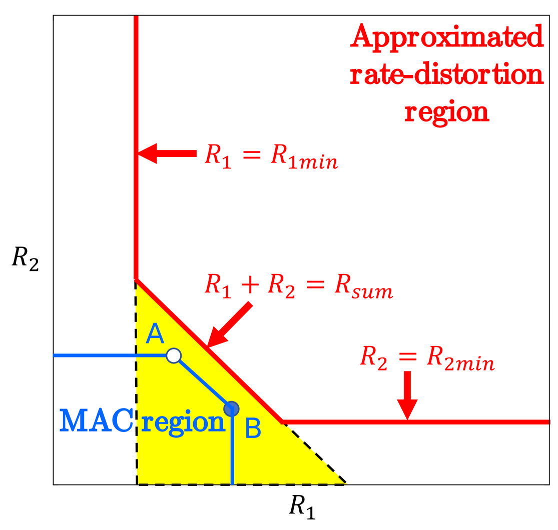


Information-theoretic analysis

- We derived an analytical expression of the rate-distortion region:

$$\mathcal{R}(D_1, D_2) = \left\{ (R_H, R_1, R_2) \text{ s.t. } \lim_{n\to\infty} \mathbb{E}[d(\mathbf{x}_1^n, \hat{\mathbf{x}}_1^n)] \le D_1, \lim_{n\to\infty} \mathbb{E}[d(\mathbf{x}_2^n, \hat{\mathbf{x}}_2^n)] \le D_2 \right\}$$

- The channel is taken into account through an outage probability analysis



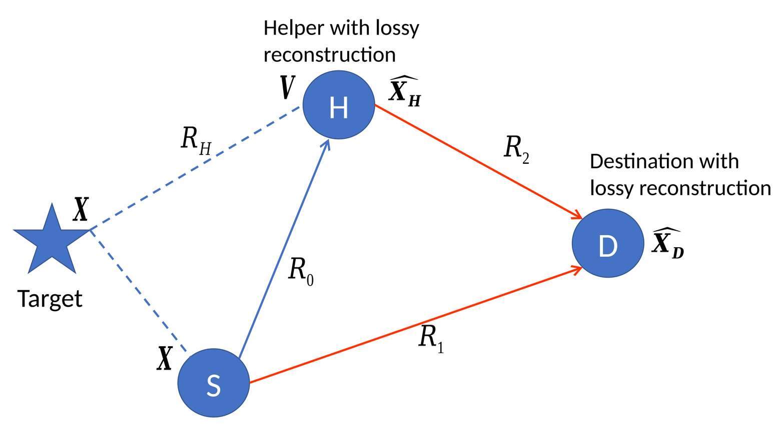
Follow-up

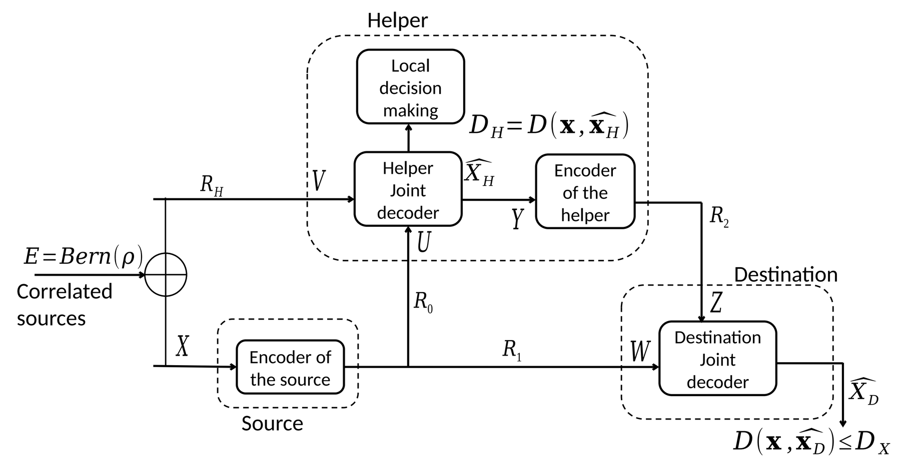
- Design practical coding schemes
- Consider an arbitrary number of sensors

3. Wyner-Ziv coding with mixed communication objectives

Model

- Reconstruction of one binary source with a **helper**: $V = X \oplus E$
- Transmission over orthogonal block Rayleigh fading channels
- **The same source is processed under two different performance metrics**

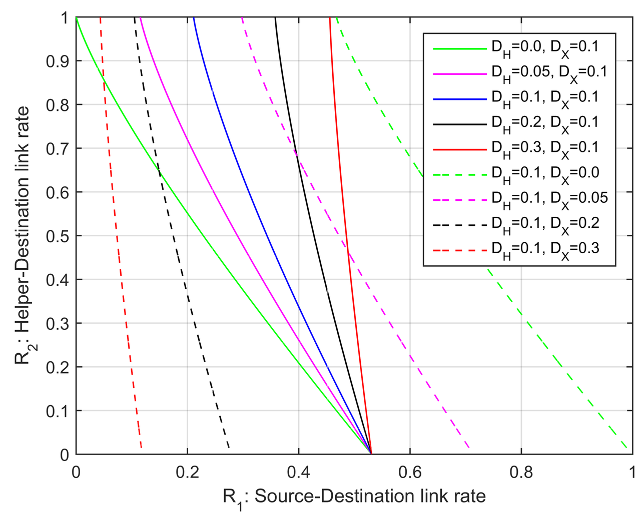




Information-theoretic analysis

- We derived generic analytical expressions of the rate-distortion region + outage probability analysis
- We found an upper bound relating the distortion criterion D_H **(helper) and** D_X **(destination)**:

$$D_H \le \psi(\rho, \psi(D_X, H_b^{-1}(R_1 + H_b(D_X)))), \quad \Psi(y,t) = \left(\frac{y-t}{2y-1}\right)$$



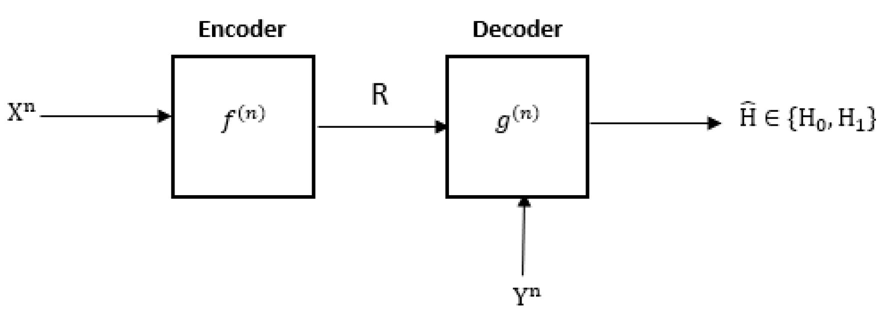
Follow-up

- Design practical coding schemes
- Consider mixed criterion: *e.g.*, decision making at the helper, distortion at the destination

4. Information-theoretic bounds for DHT

Model

- Distributed Hypothesis Testing (DHT) for **general sources** $(\mathbf{X}^n, \mathbf{Y}^n)$:
  - $H_0 : (\mathbf{X}^n, \mathbf{Y}^n) \sim P_{\mathbf{X}^n, \mathbf{Y}^n}$
  - $H_1 : (\mathbf{X}^n, \mathbf{Y}^n) \sim P_{\bar{\mathbf{X}}^n, \bar{\mathbf{Y}}^n}$

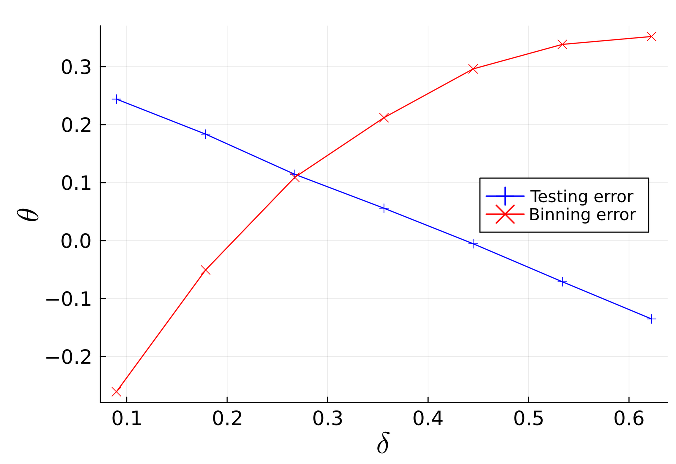


Information-theoretic analysis

- Bound the **Type-II error probability** $\beta_n = \mathbb{P}(\text{decide} H_0 | H_1) = \exp(-n\theta)$ under constraints on the **Type-I error probability** $\alpha_n = \mathbb{P}(\text{decide} H_1 | H_0)$
- From an achievable scheme based on quantization and binning, we get

$$\theta \le \min\left(r - \left(\overline{I}(\mathbf{X};\mathbf{U}) - \underline{I}(\mathbf{Y};\mathbf{U})\right), \underline{D}(P_{\mathbf{U},\mathbf{Y}} || P_{\bar{\mathbf{U}},\bar{\mathbf{Y}}}) + \left(\underline{I}(\mathbf{X};\mathbf{U}) - \overline{I}(\mathbf{X};\mathbf{U})\right) \right)$$

- We have specialized the bound for non i.i.d. **Gaussian models** and for **Gilbert-Elliot Models**



Follow-up

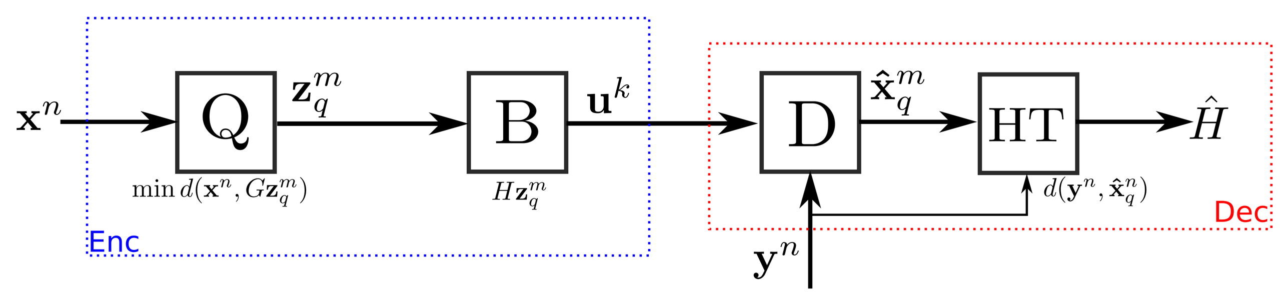
- Consider joint decision/reconstruction setup
- Consider some more complex communication scenario

5. Practical coding schemes for DHT

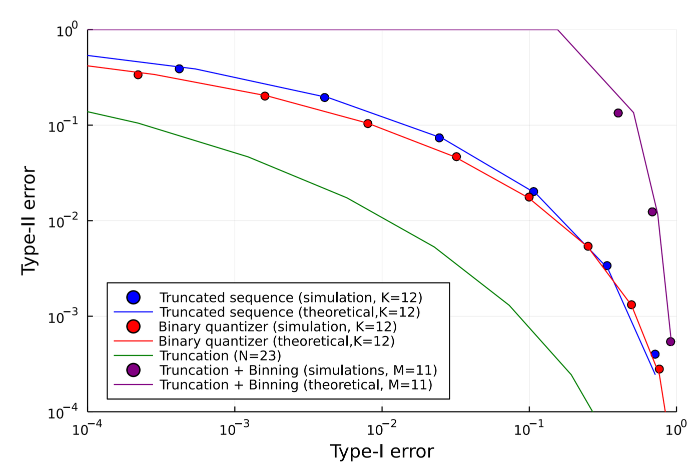
Model

- Practical DHT for **binary sources**: $\mathbf{Y} = \mathbf{X} \oplus \mathbf{V}$ $X, Y \sim \mathcal{B}(0.5)$, $\mathbf{V} \sim \mathcal{B}(\rho)$
  - $H_0 : \rho = p_0$
  - $H_1 : \rho = p_1 > p_0$

Practical coding scheme



- Two-steps coding scheme: quantization and binning, both from **short linear block codes**
- **Analytical expressions** of the Type-I and Type-II error probabilities for finite n
- The proposed scheme shows better performance than the baseline
- The analytical expressions predict accurately the coding scheme performance



Follow-up

- Consider other source models (Gilbert-Elliot, Gaussian, etc.)
- Consider symmetric case (Encode X AND Y)

6. Perspectives

- Bridge the gap between the two parts of the project: investigate DHT under complex communication conditions.
- This should allow to define new problems of interest from the viewpoint of information theory and coding
- Develop practical coding schemes for those complex communication conditions