Interactive Communication for Resource Allocation

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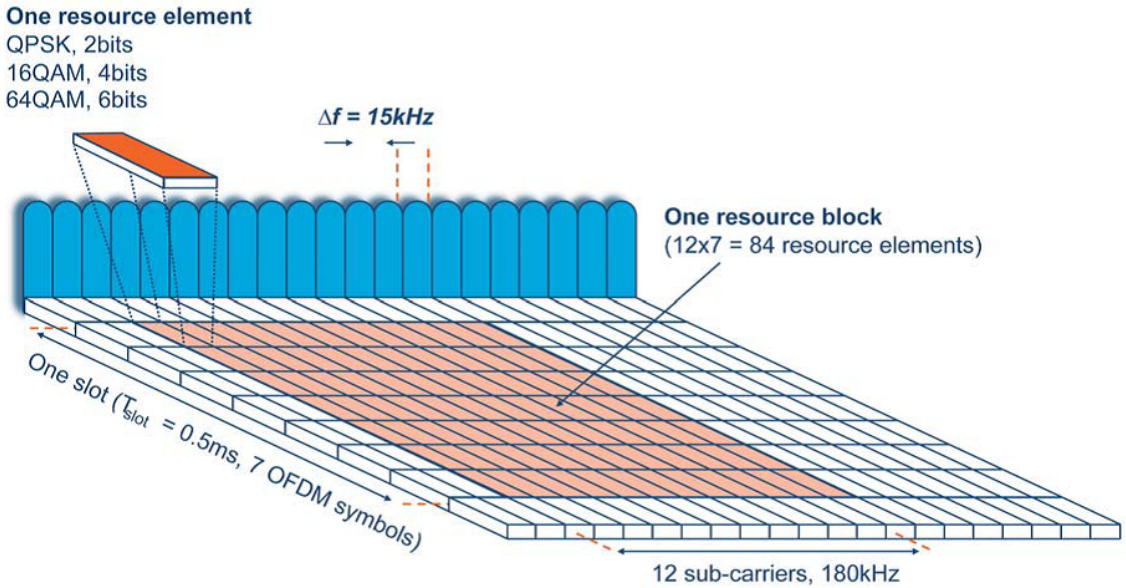
Outline

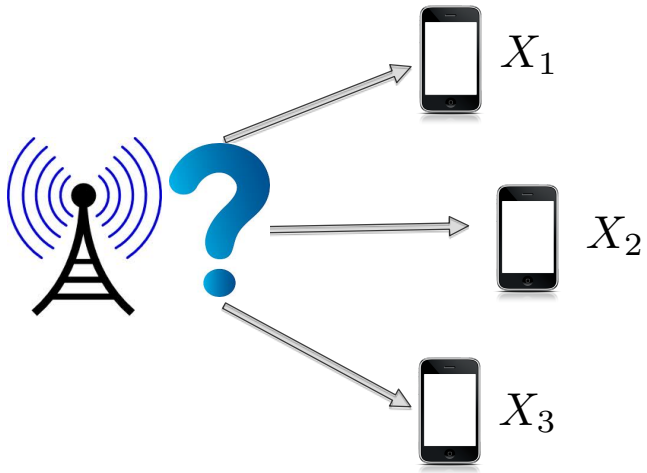
1. Introduction
2. Problem Model
3. Analysis
4. Results
5. Conclusions

Motivation

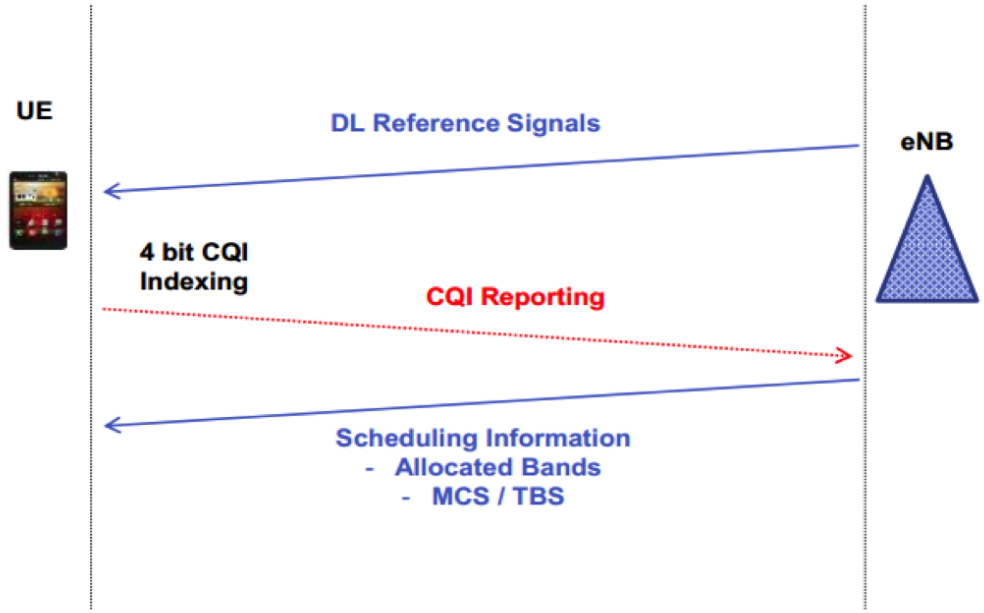


M. I. Salman etc. "IETE Technical Review"

- Which user to assign the subcarrier to
- Which modulation and coding scheme to employ



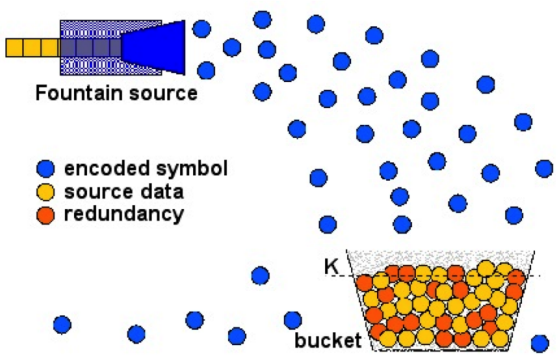
Adaptive Modulation and Coding



- Overheads
  - Reference Signals
  - Channel Quality Indicators
  - Control Decisions
- Occupy the OFDMA resource blocks
- Approximately 1/4 to 1/3 of all downlink transmission in LTE

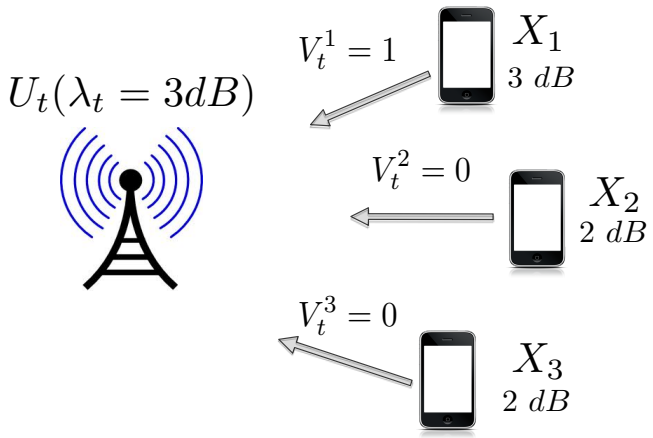
Background

Rateless Codes



http://www.telematica.polito.it/oldsite/sas-ipl/

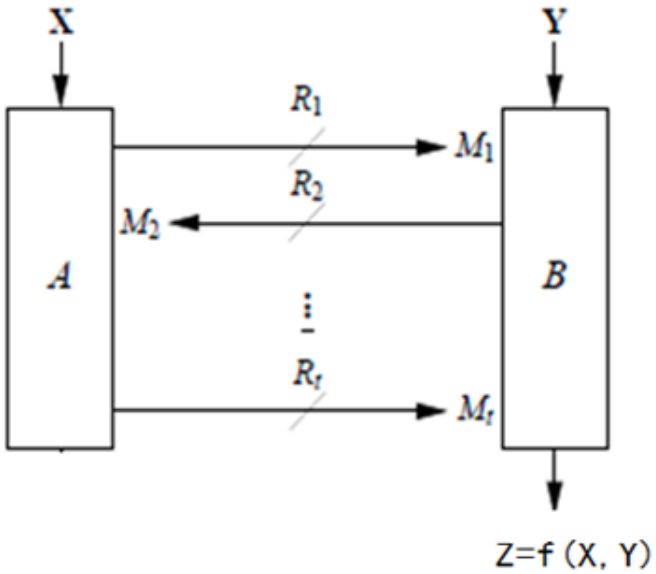
- Almost achieve channel capacity
- Without requiring of channel information at the transmitter side
- Allow variable block length



- BS: wishes to maximize the system throughput
- Only needs to learn the arg-max

Background

Interactive Communication



- Interaction for Lossy Source Reproduction (Kaspi 1985)
- Interaction for function computation (Ishwar & Ma 2011)
  - Benefit can be arbitrarily large
  - Infinite rounds interaction may help

$$\begin{aligned}\mathcal{R}_t =\{\mathbf{R}|\exists U^t,\ s.t.\forall i=1,\cdots,t \\ R_i \geq I(X;U_i|Y,U^{i-1}),\ U_i-(X,U^{i-1})-Y,\ i\ odd \\ R_i \geq I(Y;U_i|Y,U^{i-1}),\ U_i-(Y,U^{i-1})-X,\ i\ even \\ H(f(X,Y)|Y,U^t)=0\}\end{aligned} \tag{1}$$

Main Contribution

Achievable Interactive Communication Scheme for Resource Allocation

- Determine the arg-max (use rateless codes for data transmission)
- Solve by dynamic programming
- Show huge savings

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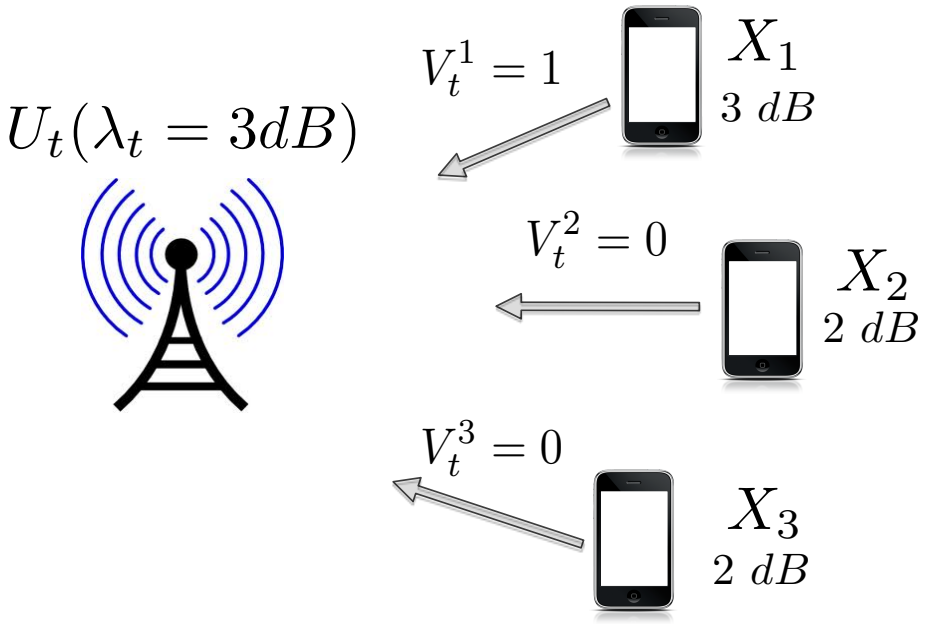
Problem Model



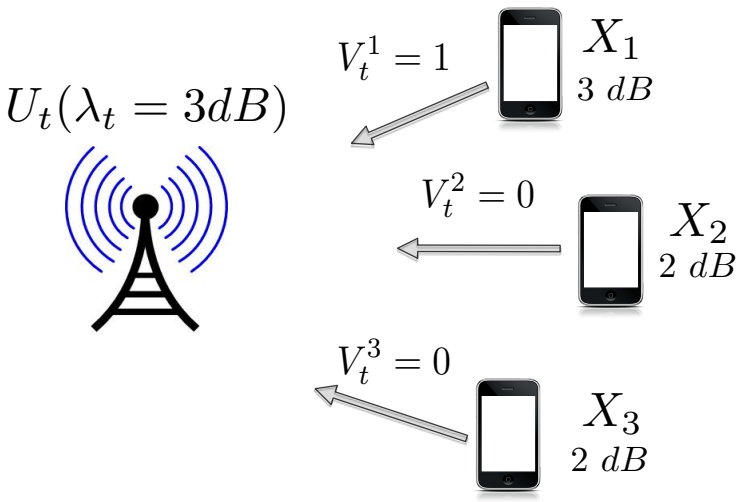
Notations

- $X_i \in \mathcal{X}_t = \{a_t, \ldots, b_t\}$
- U_t Broadcasting message at round t
- V_t^i Replied message from MS i at round t

Achievable Interaction Scheme

1: BS broadcasts a threshold λ_t at round t
2: MS i replies a 1 if $X_i \geq \lambda_t$ and 0 otherwise
3: Stops when BS knows arg-max reliably

Problem Model



Some Assumptions

- BS knows the initial distribution of X
- BS knows the initial number of MSs
- MSs are not allowed to communicate with each other

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Analysis

Non-increasing Support set of X

If some users reply 1

$$\begin{aligned} a_{t+1} &= \lambda_t \\ b_{t+1} &= b_t \\ F_{t+1}(x) &= \frac{F_t(x) - F_t(\lambda_t)}{F_t(b_t) - F_t(\lambda_t)} \end{aligned} \tag{2}$$

If no user replies 1

$$\begin{aligned} a_{t+1} &= a_t \\ b_{t+1} &= \lambda_t \\ F_{t+1}(x) &= \frac{F_t(x) - F_t(a_t)}{F_t(\lambda_t) - F_t(a_t)} \end{aligned} \tag{3}$$

Analysis

Aggregate rate

$$R_t(\lambda) = H(\lambda|\lambda_1, \cdots, \lambda_{t-1}) + N_t + (F_t(\lambda))^{N_t} R^*(N_t, a_t, \lambda) + \sum_{i=1}^{N_t} (1 - F_t(\lambda))^i F_t(\lambda)^{N_t - i} \frac{N_t!}{i!(N_t - i)!} R^*(i, \lambda, b_t) \quad (4)$$

Policy Iteration

$$\lambda_t^* = \arg\min_{\lambda} R_t(\lambda) \quad (5)$$

Analysis

- Efficiently Encode the Threshold

$$H(\lambda_t|\lambda_1,\ldots,\lambda_{t-1}) \quad (6)$$

- Why $H(N_t|N_{t-1})$ works?
  - $\mathcal{X}_t$ and N_t determines λ_t^*
  - $\mathcal{X}_{t-1}$,N_{t-1} and N_t determines $\mathcal{X}_t$

$$\mathcal{X}_t = \begin{cases} \{\lambda_{t-1}^*, b_{t-1}\} & \text{if } N_t < N_{t-1} \\ \{a_{t-1}, \lambda_{t-1}^*\} & \text{if } N_t = N_{t-1} \text{ and } \lambda_{t-1}^* > x_i \\ \{\lambda_{t-1}^*, b_{t-1}\} & \text{if } N_t = N_{t-1} \text{ and } \lambda_{t-1}^* \leq x_i \end{cases} \quad (7)$$

- Two other strategies
  - Non-conditioning Encode the Threshold: $H(\lambda_t)$
  - Encode the Number of Users: $H(N_t|N_{t-1})$

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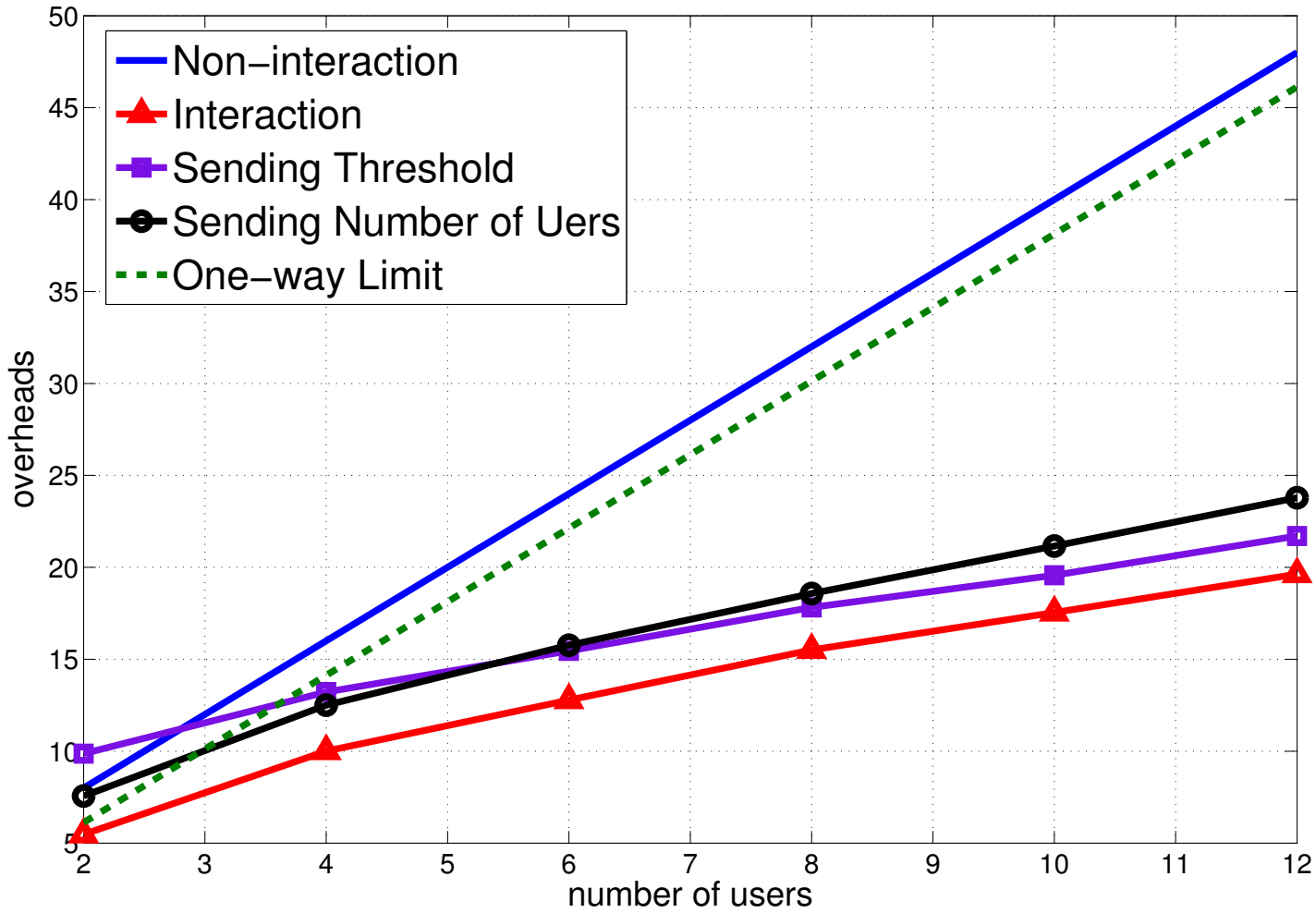
Results

- $\mathcal{X} = \{1, \ldots, 16\}$



Some Extensions

Interaction with Distortion

$$\mathbb{E}[max\{X_1, \ldots, X_{N_t}\} - X_i] \leq D \quad (8)$$

Bits Cost Vs. Time Cost

$$C = \mu R + (1 - \mu) T \quad (9)$$

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Contribution & Future Work

Review of Contribution

- Achievable Interactive Communication Scheme for Resource Allocation
- Solve by Dynamic Programming

Future Work

- Consider Scalar Quantization than the 1-bit Message
- Fundamental Limits (Rate-distortion Curve)
- Resource Allocation in MIMO system

Acknowledgments

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