MIMO Communications in Wireless Networks

Ather Gattami

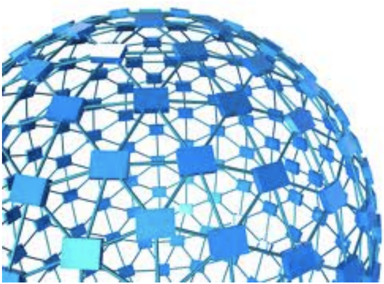
Electrical Engineering School
KTH Royal Institute of Technology
Stockholm, Sweden

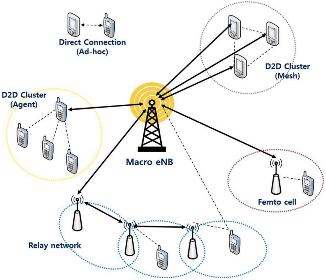
October 15, 2012

Outline

Communication and Control

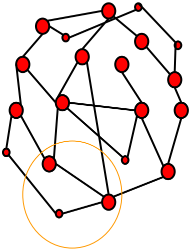
Networked Devices

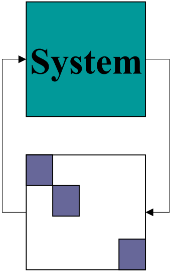




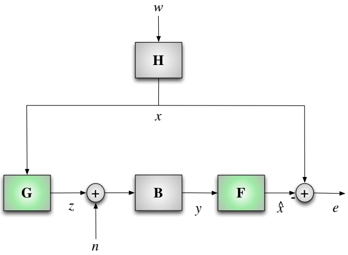
The Big Picture

Distributed decision making





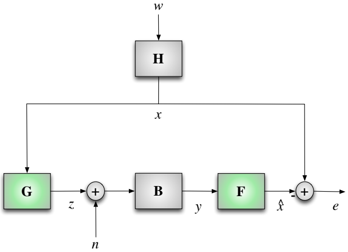
Connections to Control Theory: Estimation over Channel



$$\inf_F \sum_{k=1}^{N} \mathbf{E} \|x_k - \hat{x}_k\|^2$$

$$G(x) = \begin{bmatrix} G_1(x_1) \\ G_2(x_1, x_2) \\ \vdots \\ G_N(x_1, \ldots, x_N) \end{bmatrix}$$

Connections to Control Theory: Estimation over Channel



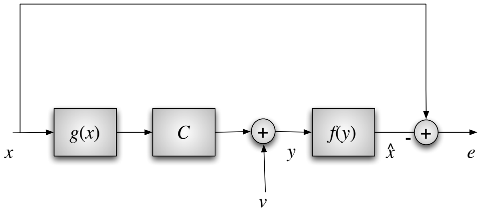
$$\inf_{F,G} \sum_{k=1}^{N} \mathbf{E}\|x_k - \hat{x}_k\|^2$$

$$G(x) = \begin{bmatrix} G_1(x_1) \\ G_2(x_1, x_2) \\ \vdots \\ G_N(x_1, \ldots, x_N) \end{bmatrix}$$

$$\mathbf{E}\|z_k\|^2 \leq P$$

Connections to Control Theory

MIMO distributed communication:

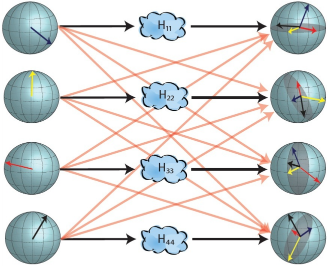


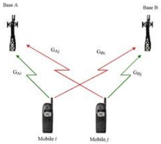
$$\inf_{\substack{f \\ \mathbf{E}\|g(x)\|^2 \le P}} \mathbf{E}\|x - \hat{x}\|^2$$

$$g(x) = \begin{bmatrix} g_1(C_1 x) \\ g_2(C_2 x) \\ \vdots \\ g_N(C_N x) \end{bmatrix}$$

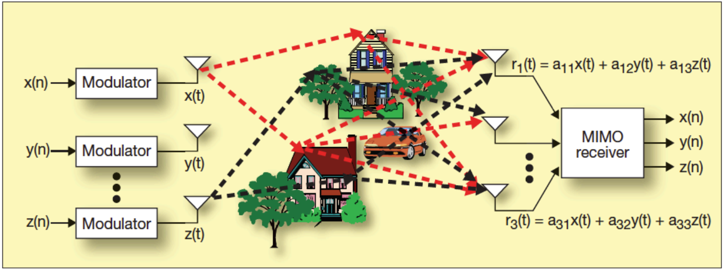
Understanding MIMO Communication

Important corner stone in distributed decision making:

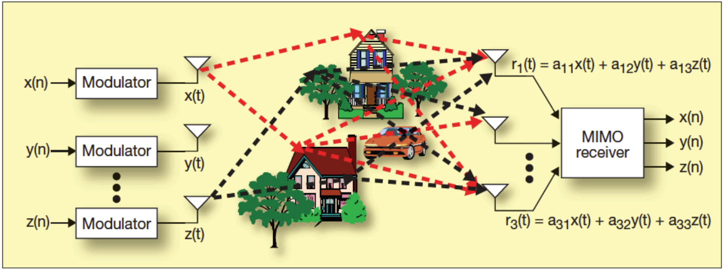




Why MIMO Communication?

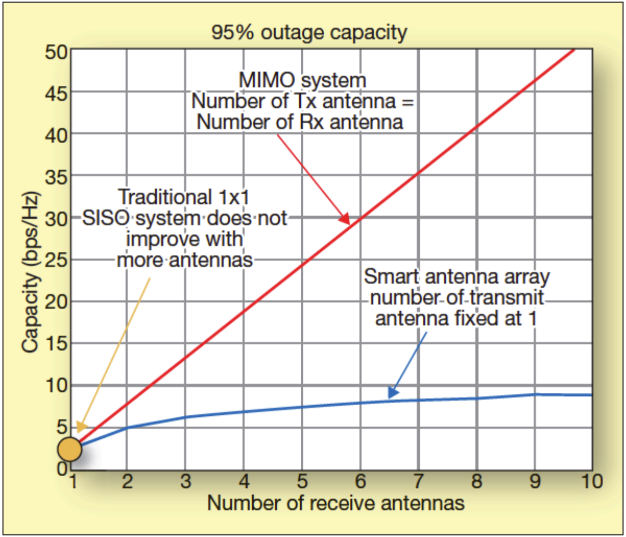


Why MIMO Communication?



MIMO systems insensitive to geometry

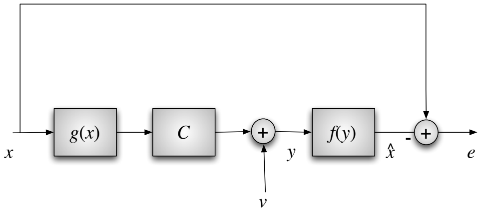
Why MIMO Communication?



Complexity of MIMO Communications

Complexity of MIMO Communications

MIMO centralized communications:

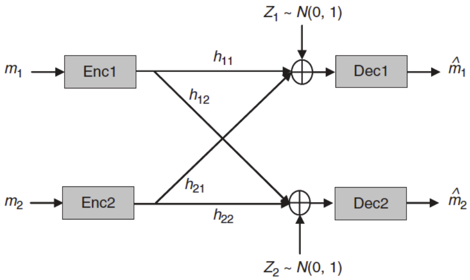


$$\inf_{\substack{f \\ \mathbf{E}\|g(x)\|^2 \leq P}} \mathbf{E}\|x - \hat{x}\|^2$$

$$g(x) = \begin{bmatrix} g_1(x) \\ g_2(x) \\ \vdots \\ g_N(x) \end{bmatrix}$$

Distributed Interference Problems

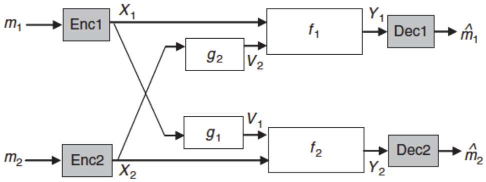
Strong versus weak interference:



[H. Sato, 1981], [T. Han and K. Kobayashi, 1981]

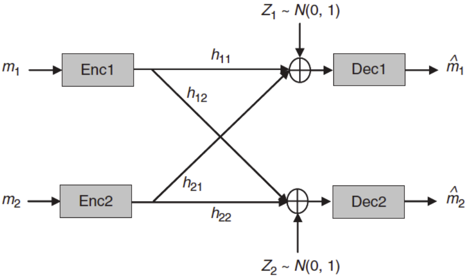
Distributed Interference Problems

Deterministic Interference Problem:



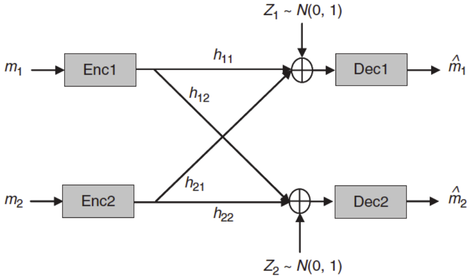
[A. El Gamal and M. Costa, 1982]

Distributed Interference Problems



$$m, n \in \mathbb{N},\ m < n,\ h_{11} = 2^n,\ h_{12} = 2^m,\ X_1 = 0.b_1 b_2 b_3 \ldots$$

Distributed Interference Problems

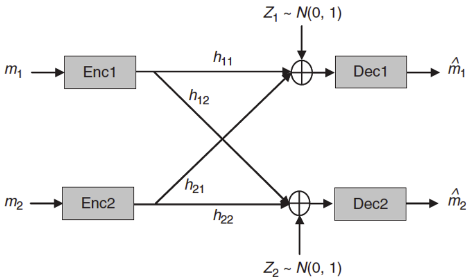


$m, n \in \mathbb{N},\ m < n,\ h_{11} = 2^n,\ h_{12} = 2^m,\ X_1 = 0.b_1 b_2 b_3 \ldots$

Signal 1(before adding noise) at receiver 1:

$b_1 b_2 \ldots b_m b_{m+1} \ldots b_n . b_{n+1} \ldots$

Distributed Interference Problems

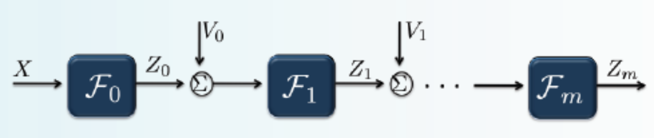


$m, n \in \mathbb{N},\ m < n,\ h_{11} = 2^n,\ h_{12} = 2^m,\ X_1 = 0.b_1 b_2 b_3 \ldots$

Signal 1(before adding noise) at receiver 1:
$b_1 b_2 \ldots b_m b_{m+1} \ldots b_n . b_{n+1} \ldots$

Signal 1(before adding noise) at receiver 2: $b_1 b_2 \ldots b_m . b_{m+1} \ldots b_n \ldots$

Deterministic versus Stochastic Modeling



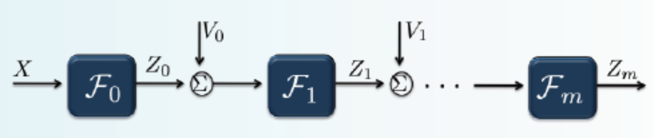
The following problem was proposed by Lipsa & Martins 2008:

$$\inf_{\mathcal{F}_i} \sup_{|X|,|V_i|\leq 1} (X - Z_m)^2 + \sigma \sum_{k=0}^{m} \mathcal{F}_k^2(Y_k)$$

$$Z_k = \mathcal{F}_k^2(Y_k)$$

$$Y_{k+1} = Z_k + V_k$$

Deterministic versus Stochastic Modeling



The following problem was proposed by Lipsa & Martins 2008:

$$\inf_{\mathcal{F}_i} \sup_{|X|,|V_i|\leq 1} (X - Z_m)^2 + \sigma \sum_{k=0}^{m} \mathcal{F}_k^2(Y_k)$$

$$Z_k = \mathcal{F}_k^2(Y_k)$$

$$Y_{k+1} = Z_k + V_k$$

Linear coding scheme is optimal for $\sigma \geq 1$!

[Gattami, 2012]

"Deterministic Team Problems with Signaling Incentive"

Ongoing Research

Some important ongoing research in open problems:

Estimation over Gaussian Channel

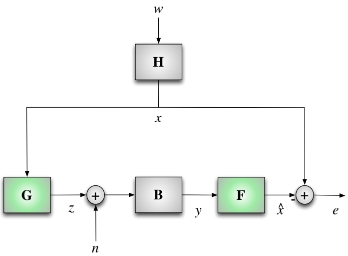
Theorem

Let **H** *be given by*

$$x(t+1) = ax(t) + bw(t)$$

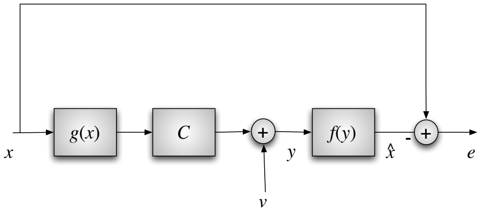
and $e(t) = x(t) - \hat{x}(t)$ *for* $t \geq 0$. *Then,*

$$\mathbf{E}\{e^2(t+1)\} \geq \frac{N}{N+P} \cdot a^2\mathbf{E}\{e^2(t)\} + b^2$$



MIMO Communication

MIMO distributed robust communications:



$$\inf_{\substack{f \\ \mathbf{E}\|g(x)\|^2 \leq P}} \sup_{\mathbf{E}\|w\|^2 \leq 1} \mathbf{E}\|x - \hat{x}\|^2$$

$$g(x) = \begin{bmatrix} g_1(C_1 x) \\ g_2(C_2 x) \\ \vdots \\ g_N(C_N x) \end{bmatrix}$$

Summary

- Strong connection between communication and control.
- Filtering over a communication channel is a MIMO communication problem.
- Robust MIMO design has a great potential in theory and applications.
- Distributed communication problems could be approached with a deterministic setting.

End of Presentation

Thank you!