New Technologies of B3G/4G

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31 July, 2009

- Introduction of Our Group
- Research Work
- Projects
- Achievements
- Family Album
- Future work

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Introduction of Our Group

- Community of associated professor, Ph.D. and M.S. students.
- Research Interests mainly
  - Theory: Some key technologies of MIMO systems
  - Application: Development of 3G Long Term Evolution(LTE)
- Emphasize the integration of theory with practice, focus on science exchanges home and abroad to broad our scope

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Research works

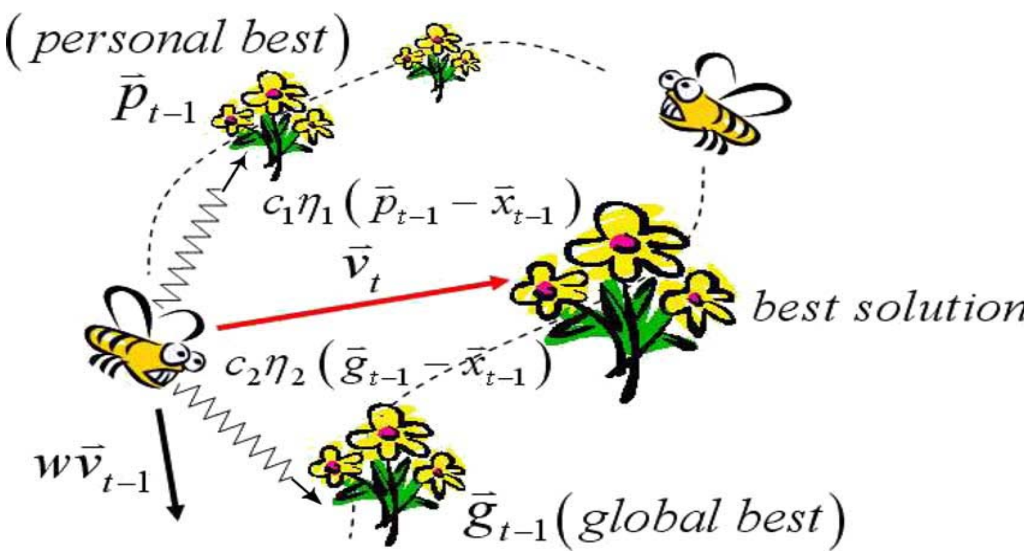
- Key technologies of MIMO systems
  - Multi-user scheduling
  - MIMO detection
- Development of 3G Long Term Evolution (LTE)
  - Link level simulation and system level simulation with/without CoMP (Coordinated Multiple Point)
  - Inter-cell Interference Co-ordination (ICIC) method
  - Inter-cell power control technology
  - Cell selection strategy for users

PSO Multi-user scheduling

- **Particle Swarm Optimization**
  - *Kennedy and Eberhart*, in 1995 , Proc. Int'l Conf. Neural Networks, vol. 5,
  - Motivated by the behaviors of bird flock or bees finding food
- **Advantage**
  - Simple, easy realization
  - low computation complexity
- **Evolutionary mechanism:**

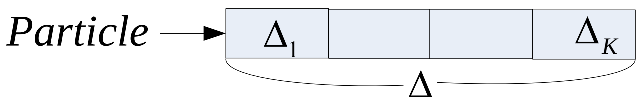
$$x_i(t) = x_i(t-1) + v_i(t)$$

$$v_i(t) = wv_i(t-1) + c_1\eta_1(pbest_i(t-1) - x_i(t-1)) + c_2\eta_2(gbest(t-1) - x_i(t-1))$$



PSO Multi-user scheduling

- Our contribution:
  - Particle definition: candidate of the scheduled user subset



$$\Delta_k = \begin{cases} 1, & kth \text{ MS selected} \\ 0, & \text{otherwise} \end{cases}$$

  - Fitness Function definition: capacity value corresponding to such particle

$$F_i(\tau) = log_2 \det(\mathbf{I}_{Nt} + \gamma \mathbf{H}^H \mathbf{H} diag(\mathbf{\Delta}(i)))$$

- Key PSO scheduling method steps

① *Initialization.* Generate certain number of particles and velocities

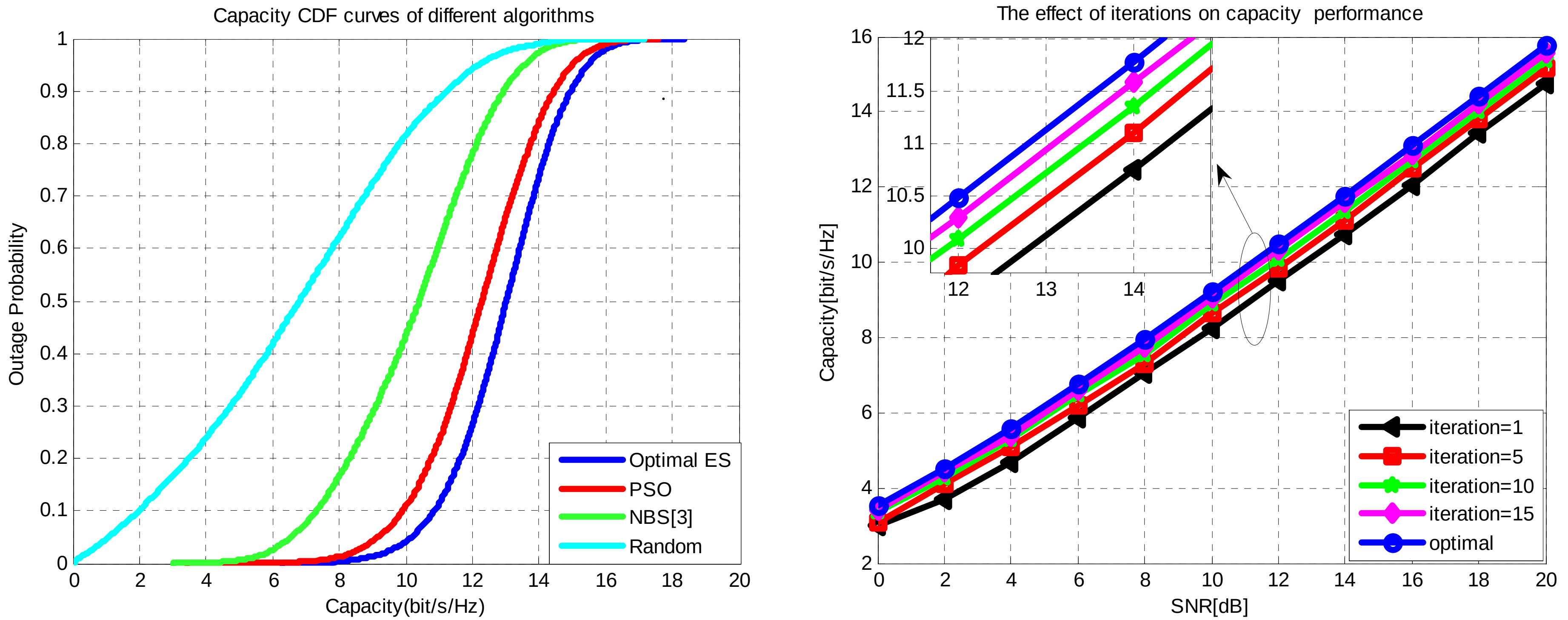
② *Evaluation.* Calculate the fitness value of each particle

③ *Evolution.* Apply PSO mechanism to these particles

④ *Termination.* Repeat the above steps until the maximal iteration number

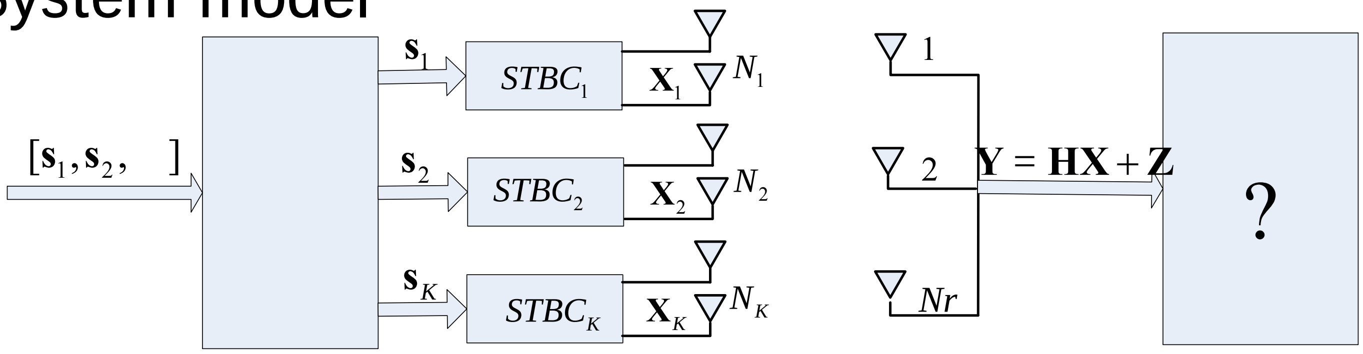
PSO Multi-user scheduling Simulation Results

- Parameters: one BS, 16 MSs with single antenna, L=4MSs scheduled
- PSO: Inertia weight factor *w*=0.9, acceleration constant c1=c2=2.0, particle number = 20 , maximal iteration number= 15



MIMO detecting

- System model



- The received signal over *T* time slots:

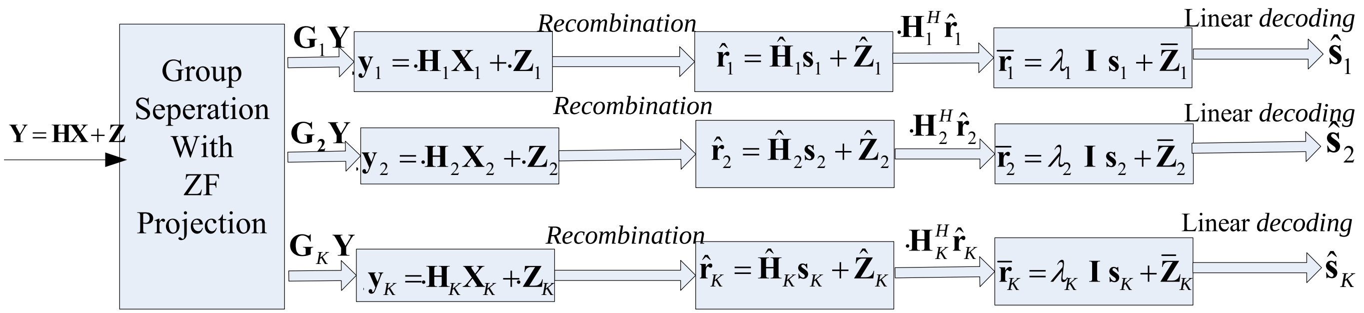
$$\mathbf{Y} = \mathbf{H}\mathbf{X} + \mathbf{Z}$$

$$= \mathbf{H}\begin{pmatrix} \mathbf{A}_{11}\mathbf{s}_1 + \mathbf{B}_{11}\mathbf{s}_1^* & \cdots & \mathbf{A}_{1T}\mathbf{s}_1 + \mathbf{B}_{1T}\mathbf{s}_1^* \\ \vdots & \ddots & \vdots \\ \mathbf{A}_{K1}\mathbf{s}_K + \mathbf{B}_{K1}\mathbf{s}_K^* & \cdots & \mathbf{A}_{KT}\mathbf{s}_K + \mathbf{B}_{KT}\mathbf{s}_K^* \end{pmatrix} + \mathbf{Z}$$

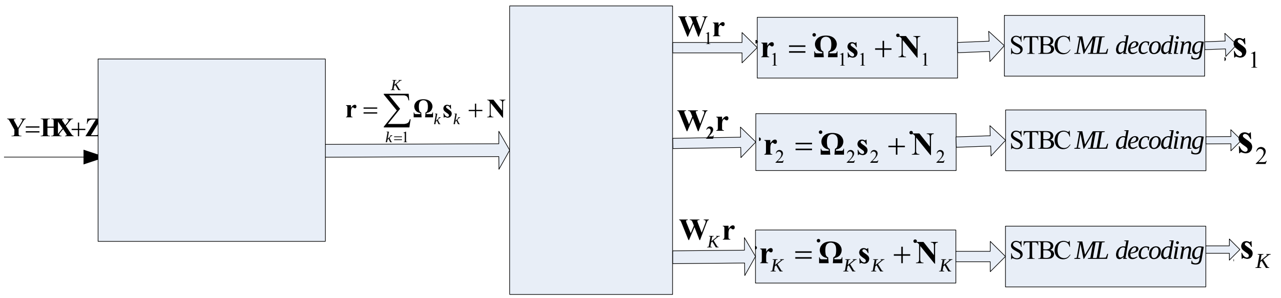
- OSTBC codeword matrix of user *k* : $\mathbf{X}_k = [\mathbf{x}_{k1}, \cdots, \mathbf{x}_{kT}] = [\mathbf{A}_{k1}\mathbf{s}_k + \mathbf{B}_{k1}\mathbf{s}_k^*, \cdots, \mathbf{A}_{kT}\mathbf{s}_k + \mathbf{B}_{kT}\mathbf{s}_k^*]$ Series
- $\mathbf{A}_t, \mathbf{B}_t, t = 1, \cdots, T$ real constant coefficient matrices of the given OSTBC.

MIMO detecting

- Two Existing Algorithms, *Lin Dai*, (IEEE Trans. Comm, vol. 53,no.9
  - Type1 detecting:

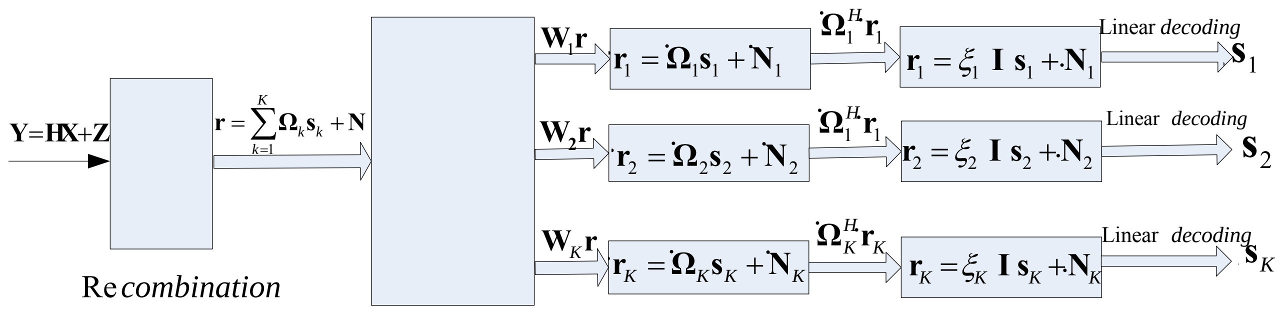


  - Type 2 detecting



MIMO detecting

- Proposed approach



- Advantages :
  - Unitary projection matrix without suffering from noise enhancement
  - Low Linear decoding complexity compared with type 2 ML decoding

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MIMO detecting

- System design under the case of transmitter employing different OSTBC
  - Assume *K* different *STBCk* ,with code length *Tk*
  - Output of *STBCk:* $\mathbf{X}_k = [\mathbf{A}_{k,1}\mathbf{s}_k + \mathbf{B}_{k,1}\mathbf{s}_k^*, \cdots, \mathbf{A}_{k,Tk}\mathbf{s}_k + \mathbf{B}_{k,Tk}\mathbf{s}_k^*]$
  - The common code length : $T = MCM\{T_1, T_2, \cdots T_K\}$ minimum common multiple
  - Define $Gk = T / T_k, k = 1 \cdots K$
- Transmit signal matrix design:

$$\mathbf{X} = [\mathbf{X}(\mathbf{A}) \quad \mathbf{X}(\mathbf{B})] = \begin{bmatrix} \mathbf{X}_1(\mathbf{A}) & \mathbf{X}_1(\mathbf{B}) \\ \mathbf{X}_2(\mathbf{A}) & \mathbf{X}_2(\mathbf{B}) \\ \vdots & \vdots \\ \mathbf{X}_K(\mathbf{A}) & \mathbf{X}_K(\mathbf{B}) \end{bmatrix} = \begin{bmatrix} \mathbf{X}_{1,1}(\mathbf{A}) & \cdots & \mathbf{X}_{1,G1}(\mathbf{A}) & \mathbf{X}_{1,1}(\mathbf{B}) & \cdots & \mathbf{X}_{1,G1}(\mathbf{B}) \\ \mathbf{X}_{2,1}(\mathbf{A}) & \cdots & \mathbf{X}_{2,G2}(\mathbf{A}) & \mathbf{X}_{2,1}(\mathbf{B}) & \cdots & \mathbf{X}_{2,G2}(\mathbf{B}) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \mathbf{X}_{K,1}(\mathbf{A}) & \cdots & \mathbf{X}_{K,GK}(\mathbf{A}) & \mathbf{X}_{K,1}(\mathbf{B}) & \cdots & \mathbf{X}_{K,GK}(\mathbf{B}) \end{bmatrix}$$

- $\mathbf{X}_{k,j}(\mathbf{A})$ represents the output code matrix where imag coefficient matrices $\mathbf{B}_k = \mathbf{0}$
- $\mathbf{X}_{k,j}(\mathbf{B})$ represents the output code matrix where real coefficient matrices $\mathbf{A}_k = \mathbf{0}$

MIMO detecting

- The received signal over T time slots:

$$\mathbf{Y} = \mathbf{H}\mathbf{X} + \mathbf{Z} = \mathbf{H}_1\mathbf{X}_1 + \mathbf{H}_2\mathbf{X}_2 + \cdots + \mathbf{H}_K\mathbf{X}_K + \mathbf{Z}$$

- With the proposed detecting approach
- For the *kth* group, receive vector: $\hat{\mathbf{r}}_k = \mathbf{W}_k\mathbf{r} = \hat{\mathbf{\Omega}}_k\mathbf{s}_k + \hat{\mathbf{n}}_k$

$$\left[\hat{\mathbf{r}}_{k,1} \quad \cdots \quad \hat{\mathbf{r}}_{k,Gk}\right] = \hat{\mathbf{\Omega}}_k[\mathbf{s}_{k,1} \quad \cdots \quad \mathbf{s}_{k,Gk}] + \left[\hat{\mathbf{n}}_{k,1} \quad \cdots \quad \hat{\mathbf{n}}_{k,Gk}\right]$$

- For each subgroup: $\hat{\mathbf{r}}_{ki} = \hat{\mathbf{\Omega}}_k\mathbf{s}_{ki} + \hat{\mathbf{n}}_{ki},\ i = 1, \cdots, G_k$
- The desired signal of each subgroup can be decoded by:

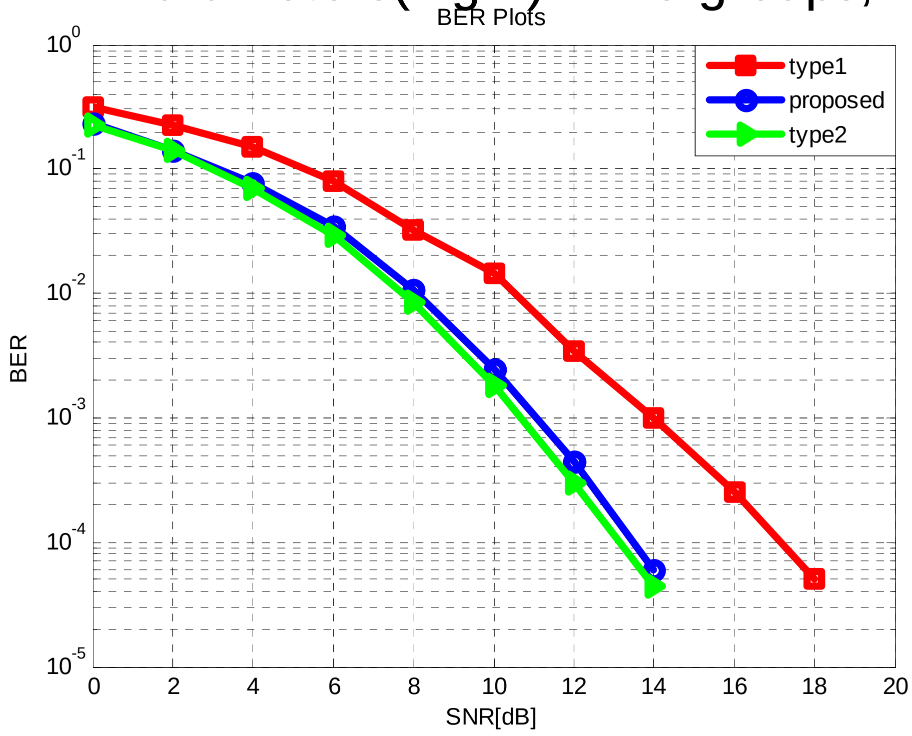
$$\tilde{\mathbf{r}}_{ki} = \hat{\mathbf{\Omega}}_k^H\hat{\mathbf{r}}_{ki} = \xi_k \cdot \mathbf{s}_{ki} + \tilde{\mathbf{n}}_{ki}$$

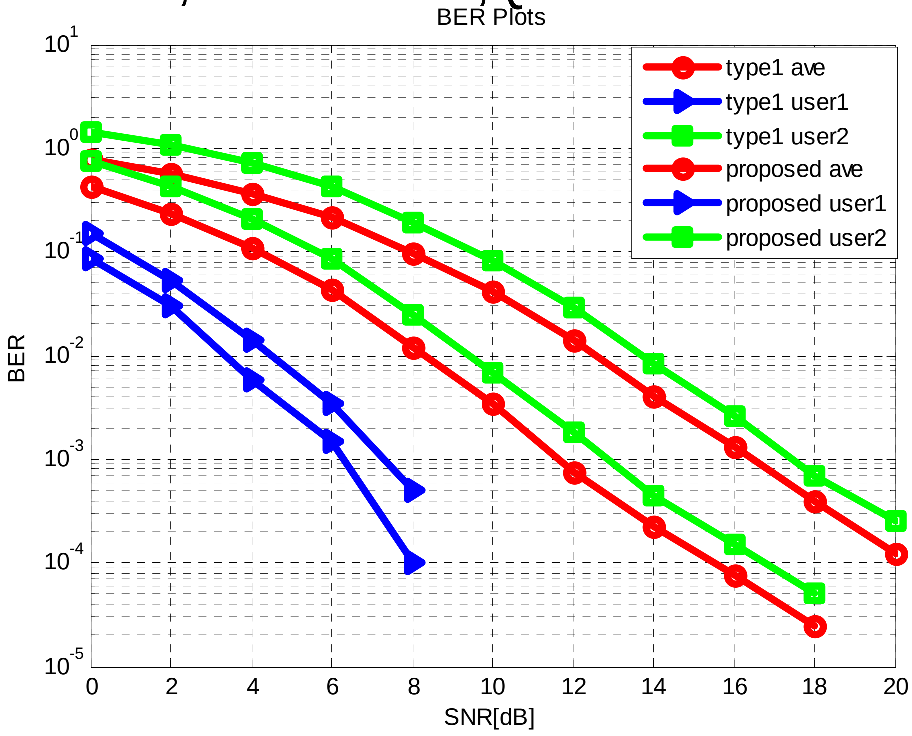
- Note that the equivalent channel of any group has the orthogonal property

$$\hat{\mathbf{\Omega}}_k^H\hat{\mathbf{\Omega}}_k = \xi_k \cdot \mathbf{I}$$

MIMO detecting Simulation Results

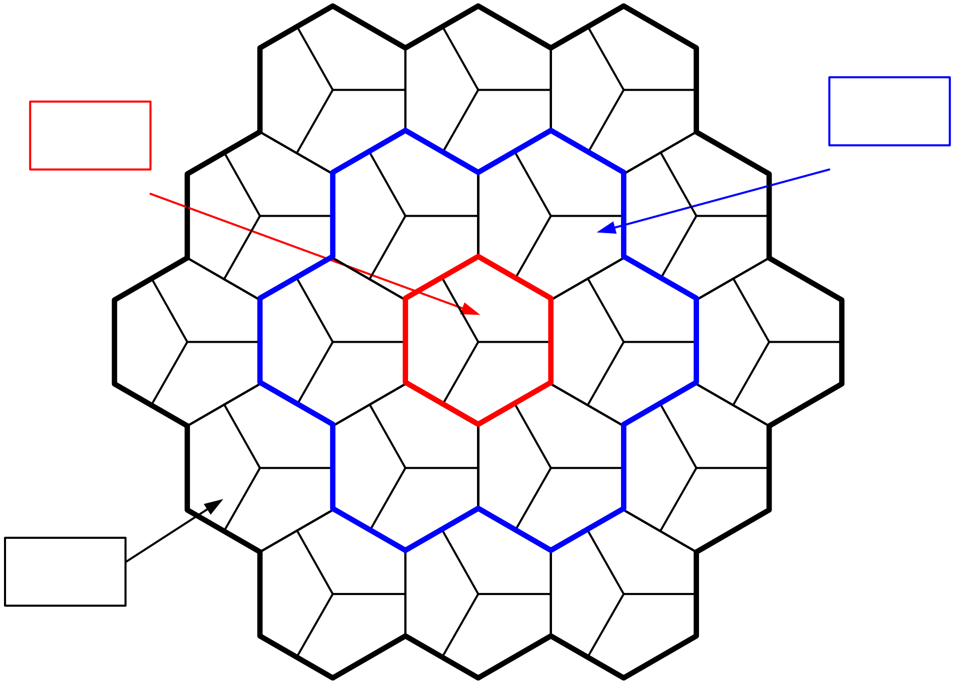
- Parameters(Fig.1):Two groups, Alamouti coding, QPSK,
- Parameters(Fig.2): Two groups, Alamouti, 3*8 OSTBC,QPSK

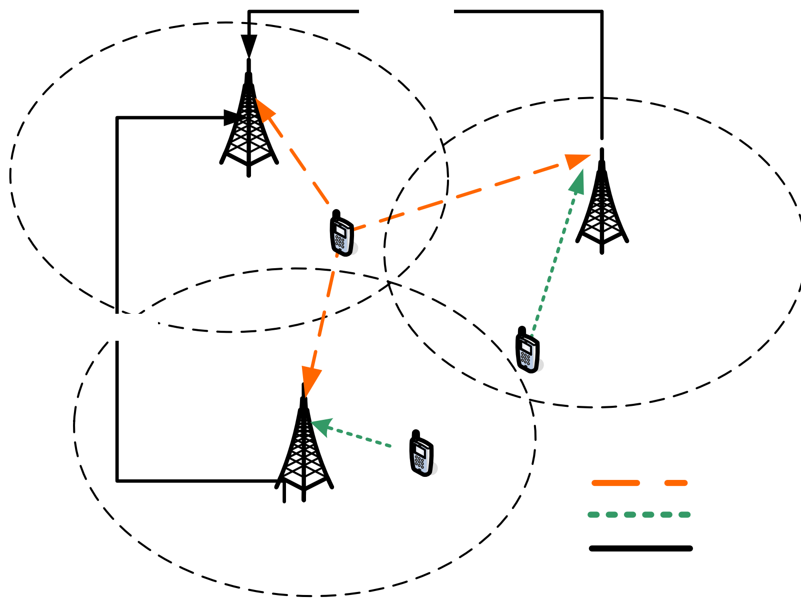




Platform of LTE/LTE-A

- Link level simulation
- System level simulation





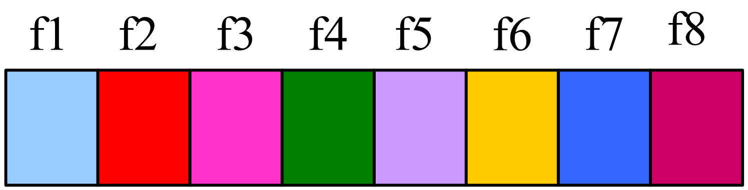
System level simulation with CoMP

For UL-CoMP, a specific UE is processed not only by its serving cell, but also by its neighbor cell ,as its coordinate cell.

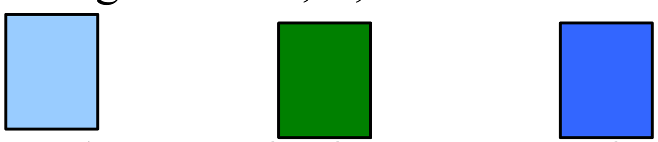
eNB1

Inter-cell Interference Co-ordination (ICIC)

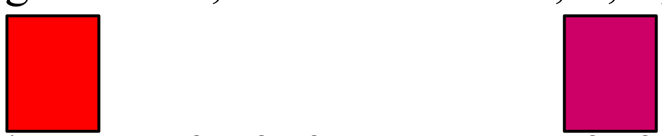
The whole band is equally divided into eight sub-bands B=f1+f2+...f8



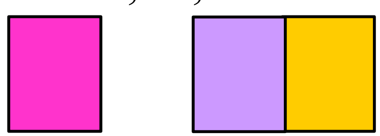
Sector A: edge user :f1,f4,f7 centre user:f2,f3,f5,f6,f8



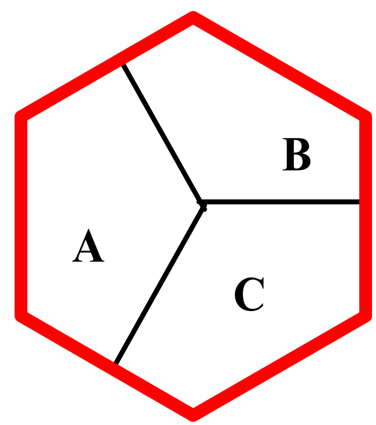
Sector B: edge user :f2, f8 centre user:f1,f3,f4,f5,f6,f7



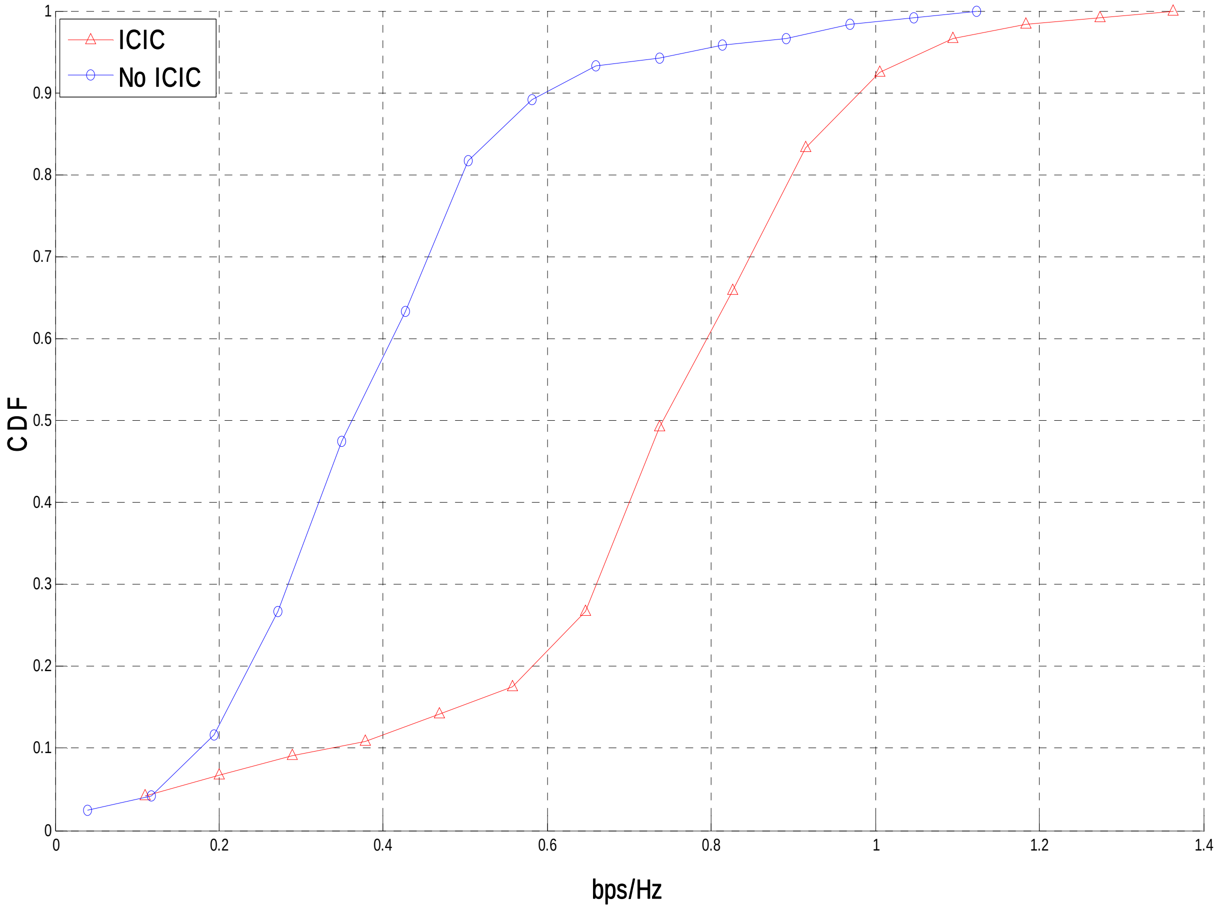
Sector C: edge user :f3, f5,f6 centre user:f1,f2,f4,f7,f8



3 sectors per cell-site



Inter-cell Interference Co-ordination (ICIC)



Inter-cell Power control

- Power control in CoMP: to achieve maximum throughput
- The proposed power reallocation scheme
  - (1) Power requisition: UEs get power value according to LTE Rel.8 uplink power control formula

$$P = \min\{P_{\max}, 10 \cdot \log_{10}^{M} + P_{0\_PUSCH} + \alpha \cdot PL + \Delta_{MCS} + f(\Delta_i)\}$$

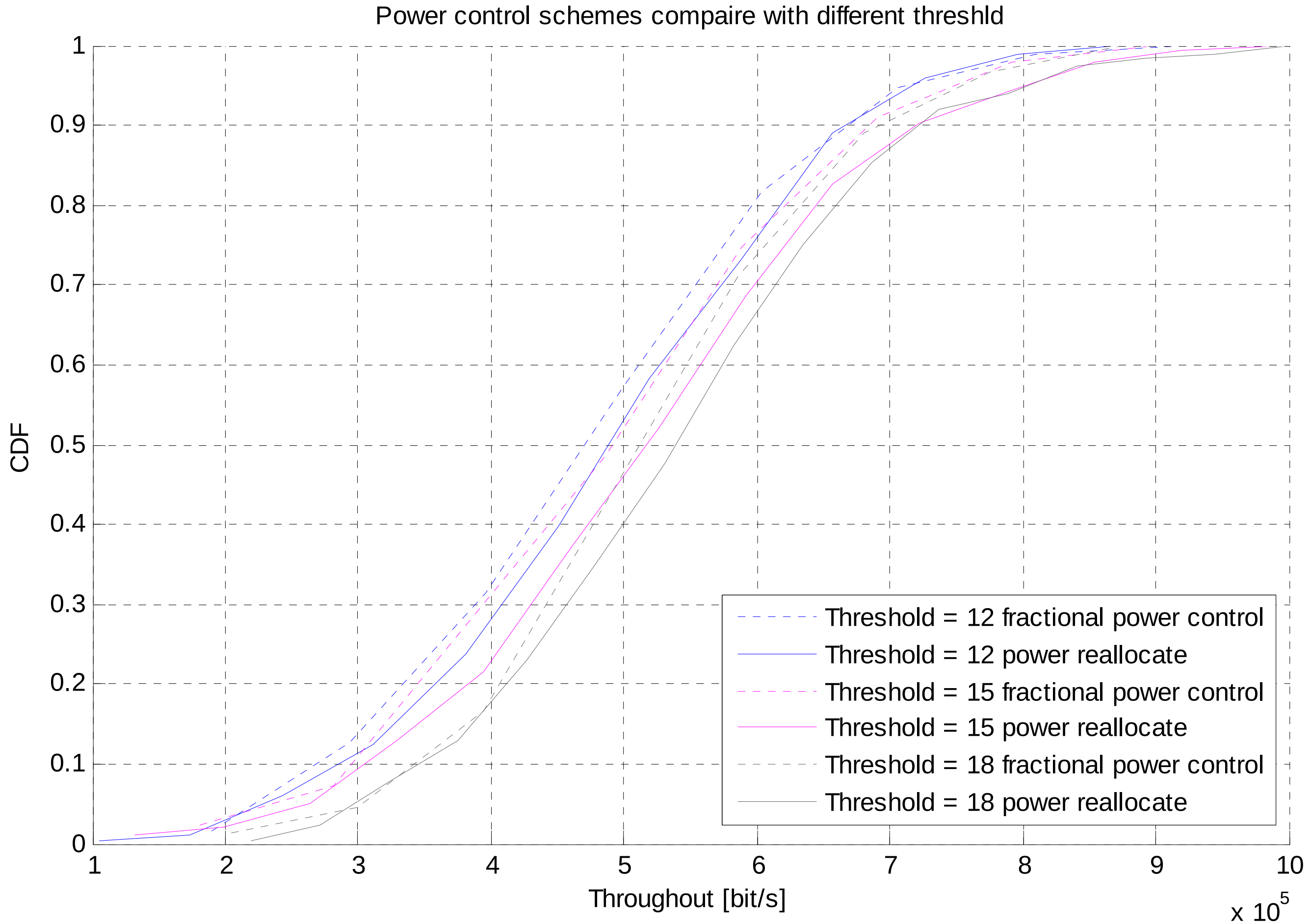
Inter-cell Power control

- (2) Power reallocation: each UE transmit power is calculated by

$$\begin{cases} p_{11} + p_{22} + p_{33} = p \\ p'_{11} : p'_{22} : p'_{33} = (g_{11}) : (g_{22}) : (g_{33}) \end{cases} \qquad \begin{cases} p'_{11} = \dfrac{g_{11}}{g_{11} + g_{22} + g_{33}} p \\ p'_{22} = \dfrac{g_{22}}{g_{11} + g_{22} + g_{33}} p \\ p'_{33} = \dfrac{g_{33}}{g_{11} + g_{22} + g_{33}} p \end{cases}$$

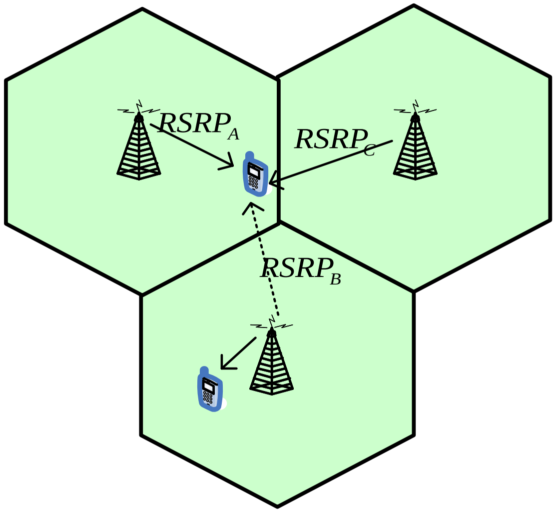
- This scheme does not increase the total power of system

Inter-cell Power control



Cell Selection algorithm

- Cell-selection with CoMP in Uplink
  - Exploit inter-cell diversity,
  - Increase cellular capacity,
  - Balance the traffic densities.



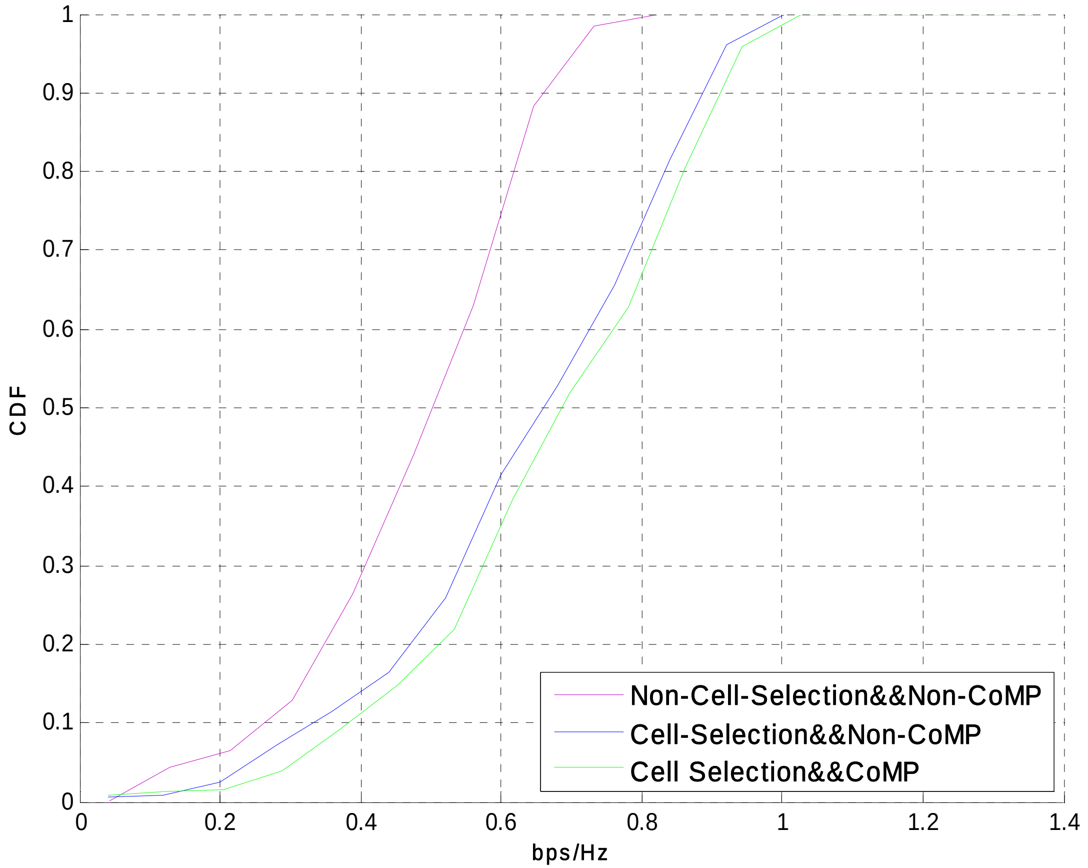
Cell selection

Cell Selection algorithm

The proposed scheme

- Determine the serving eNB
  - Determine the specified UE type: cell-edge UE or center UE
  - Decide the serving eNB for the specified UE according to the RSRP of each eNB
- Determine the CoMP set
  - When serving eNB is the originally accessed eNB, determine the number of coordinated cell in active CoMP set.
  - When serving eNB is not the originally accessed eNB, decide whether the CoMP is needed or not and the number of coordinated cells in active CoMP set.

Cell Selection algorithm



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Projects within 3 years

- Key technologies of adaptive multi-user MIMO systems，**National Science Foundation of China**，2008-2010
- Solutions on improving the throughput of edge cells for IMT-Advanced systems，**Specialized project for state key laboratory**，2008-2009
- Key technologies on MIMO for the uplink LTE systems，**Project of ZTE corporation**，2007-2008
- Enhanced technologies on MIMO for uplink LTE systems，**Project of ZTE corporation**，2008-2009

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Achievements of our group

- Achievements:
  - About 30 papers
  - 2 books
  - 1 translation
  - 4 patents
  - 4 proposal of B3G/4G

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Future work

- Multi-user MIMO systems
  - Multi-user Precoding
  - Multi-user scheduling combing with precoding
- Cross-layer design
  - Combing MIMO-OFDM With MAC protocol
- Cognitive radio
  - Cognitive coexistences between WLAN and LTE systems

Thanks for your attention!