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CC-CDMA for B3G Wireless Communications : an overview and some open issues

Mobile Systems and Solutions

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30.10.2003

OUTLINE

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B3G Motivation

- Maturing of 3G technologies motivates us to think about the possible B3G architectures
- At present it is not clear how the mobile communications beyond 3G (B3G) will look like
- The wide-band mobile communication B3G systems have to offer a wide variety of interactive multimedia services based on variable data rates for maximum number of users, global mobility, service portability, …
- It is expected that they should deliver a much higher data rate than is achievable in current systems (up to 100 Mbps)
- How to guarantee such a high data rate and what types of air-link architecture should be used

Conventional CDMA approach

Let $I = [i_1, i_2, \cdots, i_k, \cdots, i_N]$ be information signal

and

$A_1 = [a_{11}, a_{12}, \cdots, a_{1L}]$ signature code of user #1

$i_1 \cdot A_1$	$i_2 \cdot A_1$	$i_3 \cdot A_1$	$\cdots$	$i_N \cdot A_1$

Fig.1: General CDMA spreading

CC-CDMA Approach

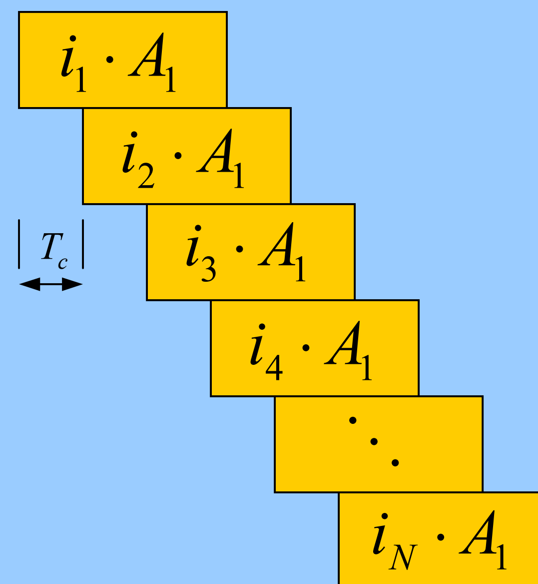
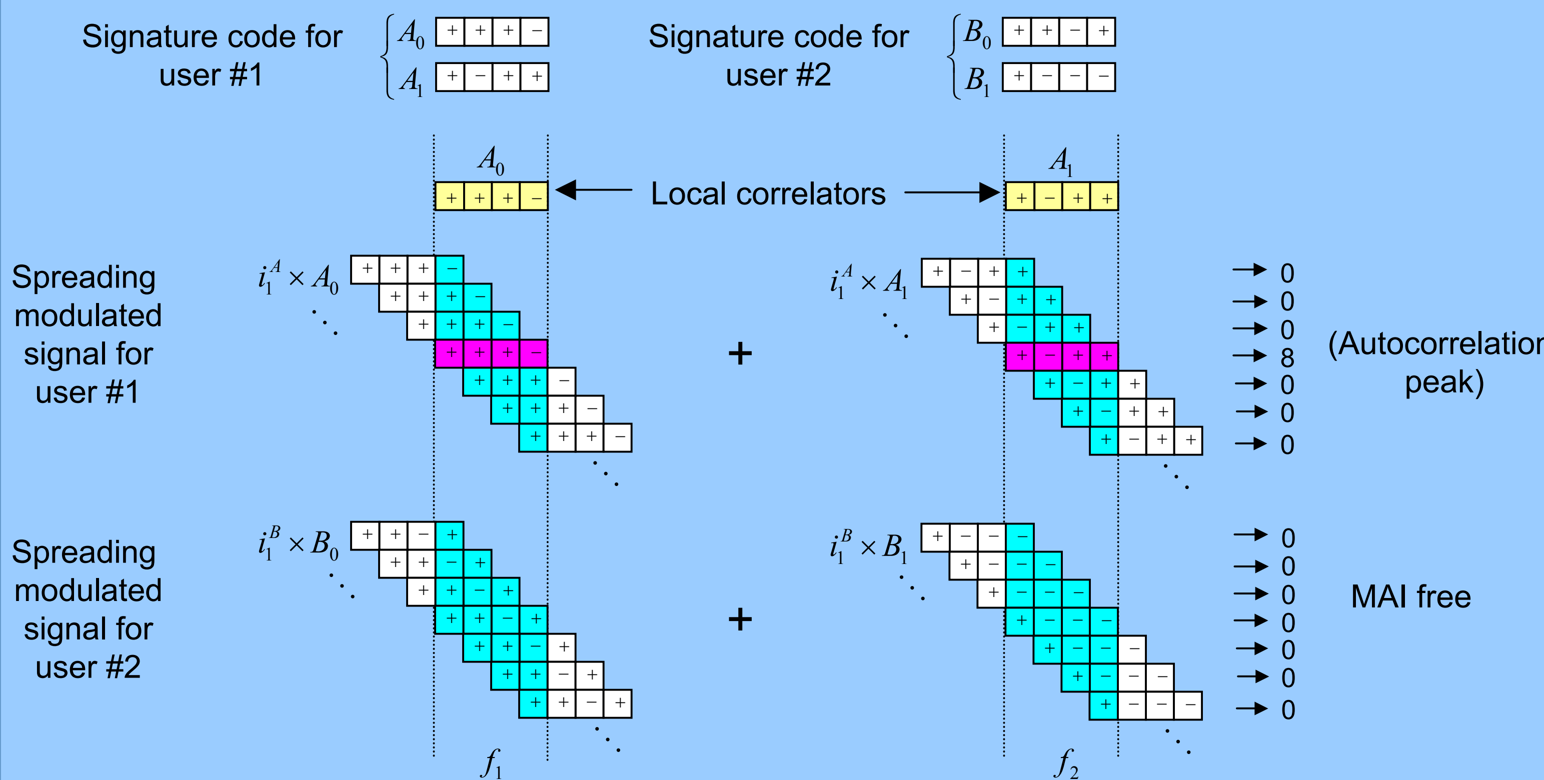


Fig.2: Offset stacked spreading

Conceptual Diagram Of DL RX



In-phase autocorrelation peak (desired bit) | The interference to the desired bit | The chip not involved | Local correlator

System description 1/2

- Let $I^A = [i_1^A, i_2^A, \cdots, i_N^A]$ be the information signal of the user #1 with two signatures A_0 A_1
- Let $I^B = [i_1^B, i_2^B, \cdots, i_N^B]$ be the information signal of the user #2 employing signatures B_0 B_1
- **Transmitter :**

$$f_1 : \quad (I^A * A_0) + (I^B * B_0)$$

$$f_2 : \quad (I^A * A_1) + (I^B * B_1)$$

System description 2/2

- **Receiver of the user #1 :**

$$f_1 : \quad [(I^A * A_0) + (I^B * B_0)] * \overline{A_0}$$

$$f_2 : \quad [(I^A * A_1) + (I^B * B_1)] * A_1$$

then

$$[(I^A * A_0) + (I^B * B_0)] * \overline{A_0} + [(I^A * A_1) + (I^B * B_1)] * \overline{A_1} =$$

$$= [(I^A * A_0) * \overline{A_0} + (I^B * B_0) * \overline{A_0}] + [(I^A * A_1) * \overline{A_1} + (I^B * B_1) * \overline{A_1}] =$$

$$= [I^A * (A_0 * \overline{A_0}) + I^B * (B_0 * \overline{A_0})] + [I^A * (A_1 * \overline{A_1}) + I^B * (B_1 * \overline{A_1})] =$$

$$= [I^A * (R_{A_0 A_0} + R_{A_1 A_1})] + [I^B * (R_{A_0 B_0} + R_{A_1 B_1})]$$

MAI = 0

AAC

CC-CDMA Transmitter-Example

User #1 : $I^A = [1,0]$

User #2 : $I^B = [1,1]$

$A_0 = [+ \quad + \quad + \quad -]$

$$\begin{array}{ccccc} + & + & + & - & \\ & - & - & - & + \\ \hline 1 & 0 & 0 & -2 & 1 \end{array}$$

f_1 :

$+$

$B_0 = [+ \quad + \quad - \quad +]$

$$\begin{array}{ccccc} + & + & - & + & \\ & + & + & - & + \\ \hline 1 & 2 & 0 & 0 & 1 \end{array}$$

$= 2\ 2\ 0 - 2\ 2$

$A_1 = [+ \quad - \quad + \quad +]$

$$\begin{array}{ccccc} + & - & + & + & \\ & - & + & - & - \\ \hline 1 & -2 & 2 & 0 & -1 \end{array}$$

f_2 :

$+$

$B_1 = [+ \quad - \quad - \quad -]$

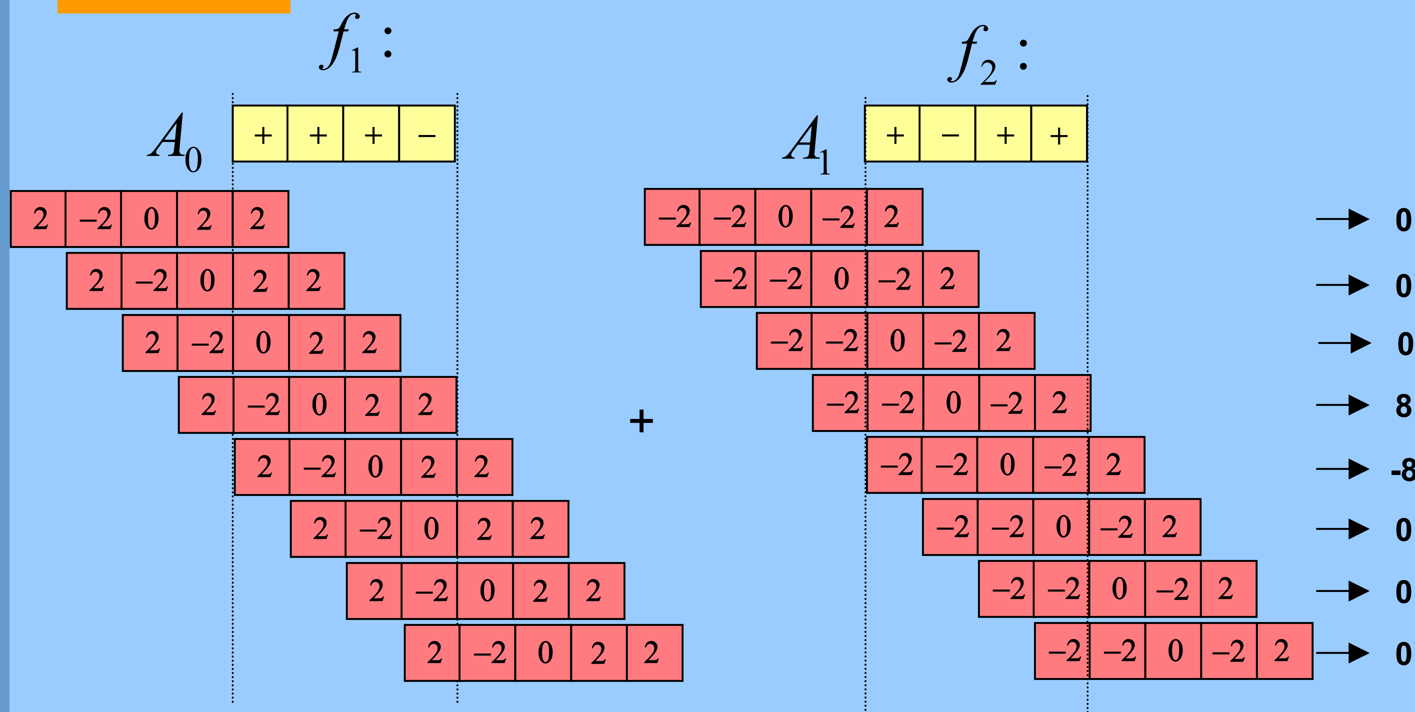
$$\begin{array}{ccccc} + & - & - & - & \\ & + & - & - & - \\ \hline 1 & 0 & -2 & -2 & -1 \end{array}$$

$= 2 - 2\ 0 - 2 - 2$

L+1 modulation levels !

CC-CDMA Receiver -Example

User #1 :



=> $I^A = [1,0]$

Spreading Efficiency 1/2

- **Spreading Efficiency (SE)** - the amount of information bits conveyed by each chip

Classical CDMA

$$SE_{CDMA} = \frac{k}{k \cdot L} = \frac{1}{L}$$

CC-CDMA

$$SE_{CC} = \lim_{k \to \infty} \frac{k}{L + (k-1)} = 1$$

$k - number\ of\ spread\ bits$

$L - length\ of\ signature\ code$

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Spreading Efficiency 2/2

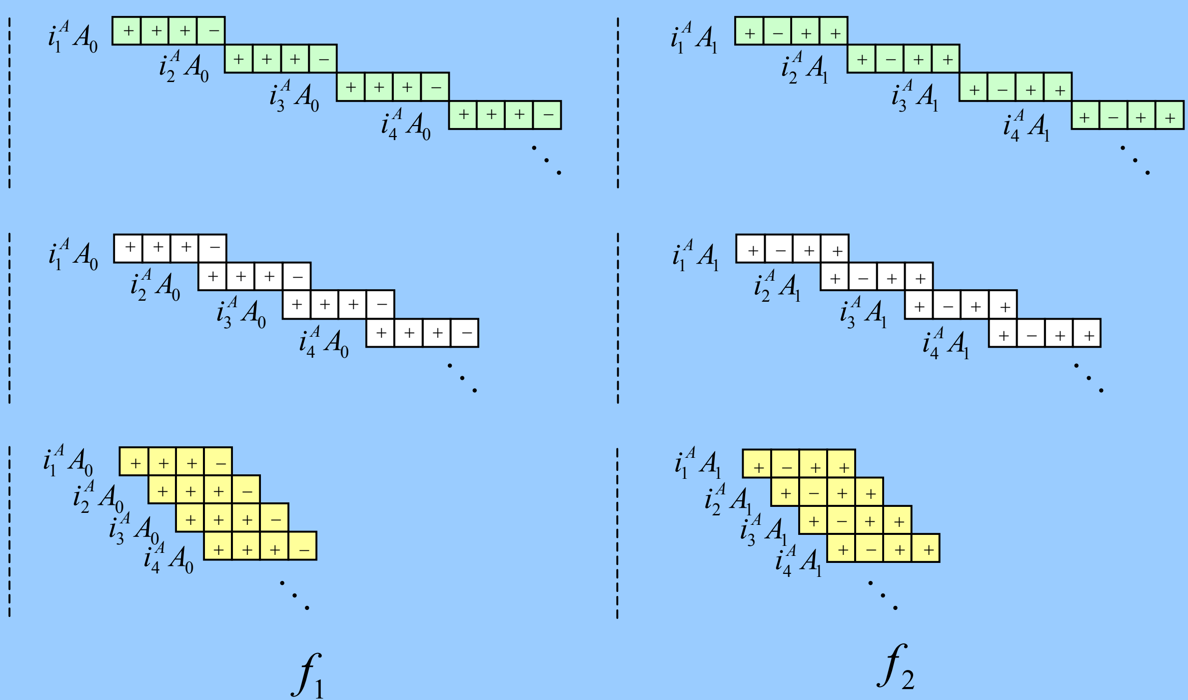
- **The highest SE** equal to one can be achieved, implying that every chip is capable of carrying one bit of information
- **Higher SE means higher bandwidth efficiency** in comparison to conventional CDMA systems under the same processing gain (PG)

Rate-Matching Algorithm 1/2

- The current 3G W-CDMA architecture is based on a **complex and sometimes difficult** rate-matching algorithm

- The new architecture is able to change the data transmission rate **“on the fly”**

Rate-Matching Algorithm 2/2



Data rate = 1
(Shift = 4)

Data rate = 4/3
(Shift = 3)

Data rate = 4
(Shift = 1)

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Codes For CC-CDMA 1/2

- **Complete Complementary Codes (CCC)**

Element code length ($L=4^n$)	**4**	**16**	**64**	**256**	**1024**	**4096**
PG ($L\sqrt{L}$)	8	64	512	4096	32768	262144
Family size ($\sqrt{L}$)	2	4	8	16	32	64
Flock size ($\sqrt{L}$)	2	4	8	16	32	64

- Drawbacks
  - Existence only for $L=4^n$
  - Relatively small family size

Codes For CC-CDMA 2/2

- **Complementary sets (CS)**

Element code length ***($L=2^n$)***	**2**	**4**	**8**	**16**	**32**	**64**
PG (L^2)	4	16	64	256	1024	4096
Flock size (L)	2	4	8	16	32	64

- Advantages
  - Existence for $L = 2^n$
  - Higher PG
  - Higher capacity

Codes For CC-CDMA Comparison

- Complete complementary codes vs. Complementary sets

Element code length ($L = 2^n$)	**2**	**4**	**8**	**16**	**32**	**64**
PG of ***N-shift CC codes***	-	8	-	64	-	512
Family size of ***N-shift CC codes***	-	2	-	4	-	8
PG of ***Complementary sets***	4	16	64	256	1024	4096
Family size of ***Complementary sets***	2	4	8	16	32	64

Codes For CC-CDMA
Summary 1/2

- **Complete complementary codes (CCC)**
  - ***Advantages***
    - Based on N-shift complementary sequences
    - Flexible recursive formula for generating of CCC
  - ***Drawbacks***
    - Existence only for $L = 4^n$
    - Relatively small family size $\Rightarrow$ low system capacity
    - Necessity to use all code elements since all elements designate AAC function of particular flock
    - If one ore more code elements are missing, AAC function contains non-zero sidelobes

Codes For CC-CDMA Summary 2/2

- **Complementary sets (CS)**

  - ***Advantages***
    - Existence for $L = 2^n$
    - Higher PG $PG_{CS} = \sqrt{L} \cdot PG_{CCC}$
    - Higher capacity $C_{CS} = \sqrt{L} \cdot C_{CCC}$
    - Recursive formula for generating

  - ***Drawbacks***
    - Code elements designating resulted AAC of particular set are general binary sequences
    - Higher sensitivity of AAC function when one or more code elements from the set are missing

Conclusion

Merits of CC-CDMA

- SE = 1: very high bandwidth efficiency
- MAI – free operation for UL & DL
- Rate matching with no need to “stop and search” for a code with specific SF

Potential improvement

- Propose code sets with higher capacity
- Improve the flexibility of the new code sets from the detection point of view
- Decrease number of modulation levels < L+1

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THANK YOU !