LA SAPIENZA

Multistage Symbol-by-Symbol Bayesian Interference Cancellation for UMTS-CDMA Links Affected by Severe Multipath

Roberto Cusani[1] , Jari Mattila[2] , Marco Di Felice[1]

[1] INFO-COM Dpt., University of Rome ‘La Sapienza‘, Italy

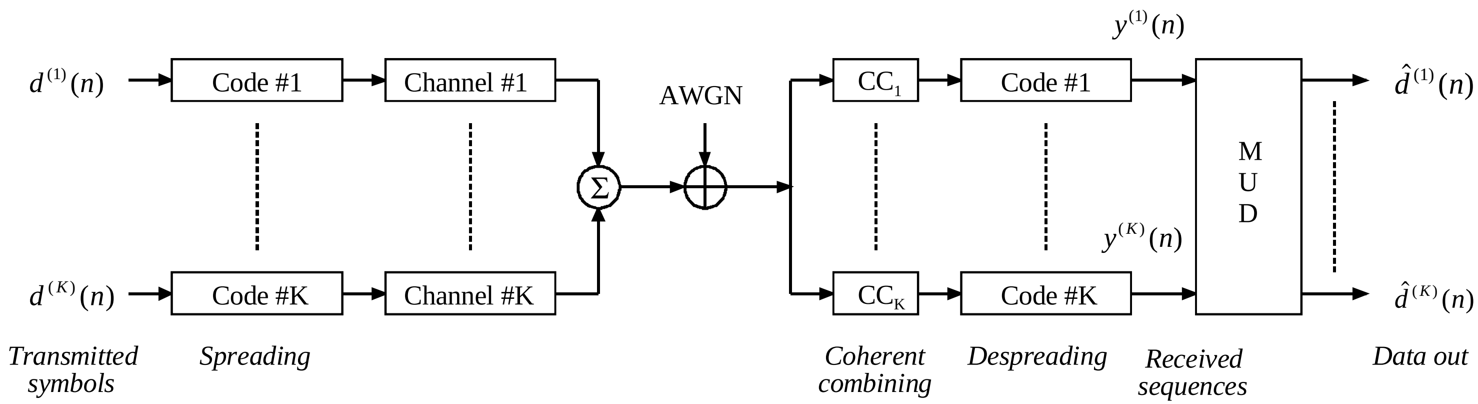
[2] Helsinki University of Technology, Commun. Lab., Finland

GLOBECOM’99, Rio de Janeiro, Brazil, December 5-9, 1999

Outline

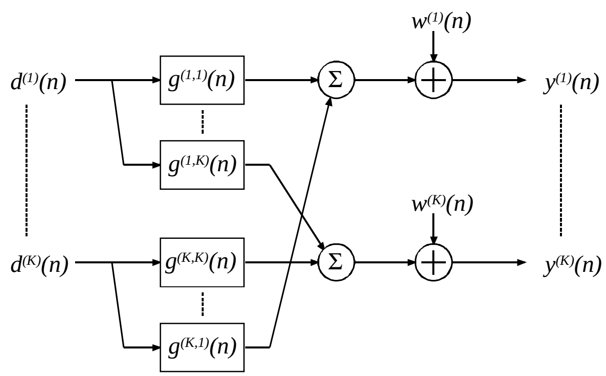
- Introduction
  - CDMA system model
- Multistage parallel interference cancellation (MPIC)
  - partial cancellation
  - Bayesian cancellation
- Simulation results
  - application to TDD-CDMA for UMTS
  - channel estimation
- Conclusions

CDMA system model



- received sequences of K users after coherent combining and despreading:

$$y^{(k)}(n) = \sum_{i=1}^{K} \sum_{m=-L_g}^{L_g} \left[g^{(i,k)}(m)\, d^{(i)}(n-m) \right] + w^{(k)}(n)$$

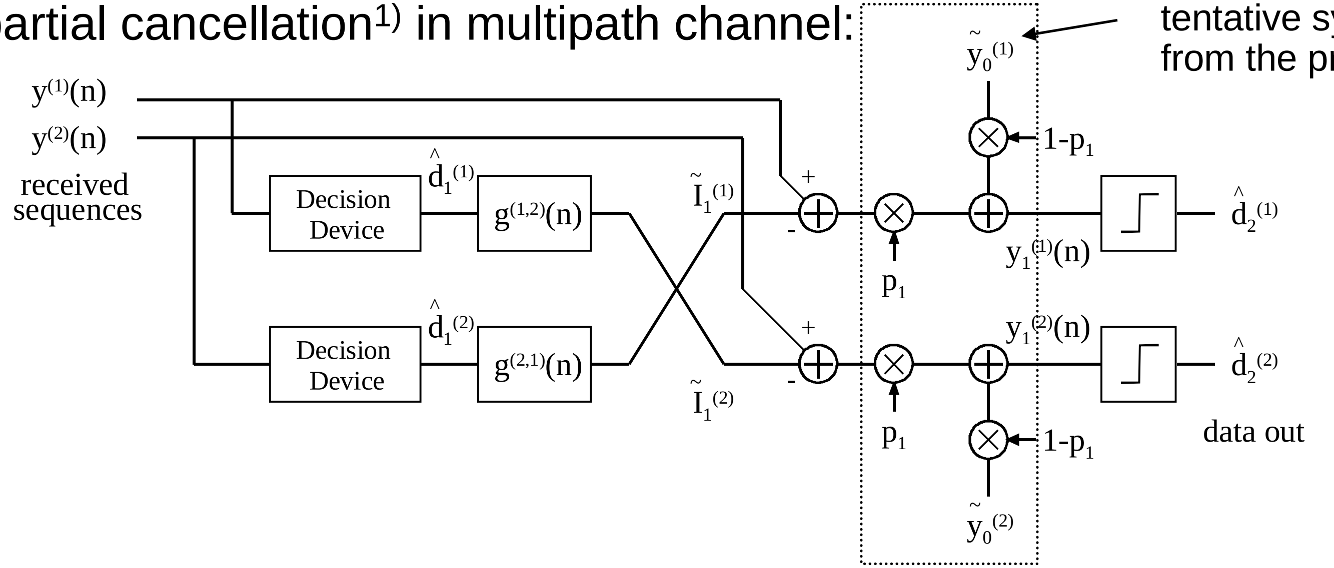


  - $\{g^{(i,k)}(n)\}$ are S-CIRs
  - $\{w^{(k)}(n)\}$ are noise sequences

Partial interference cancellation

partial cancellation:

- partial cancellation[1)] in multipath channel:



- scale the cleaned signal sample by a fraction p_1 ($0 < p_1 < 1$) and the symbol estimate from the previous stage by $1 - p_1$

$$y_1^{(k)}(n) = p_1\left[y^{(k)}(n) - \tilde{I}_1^{(k)}(n)\right] + (1 - p_1)\,\tilde{y}_0^{(k)}(n)$$

- value of fraction increases for successive stages

1) Divsalar, Simon, Raphaeli, "Improved Parallel Interference Cancellation for CDMA", 1998

MPIC detector with partial interference cancellation

- soft tentative decisions for QPSK constellation symbols {+1,-1,+j,- j} are obtained from the *hyperbolic tangent* non-linearity

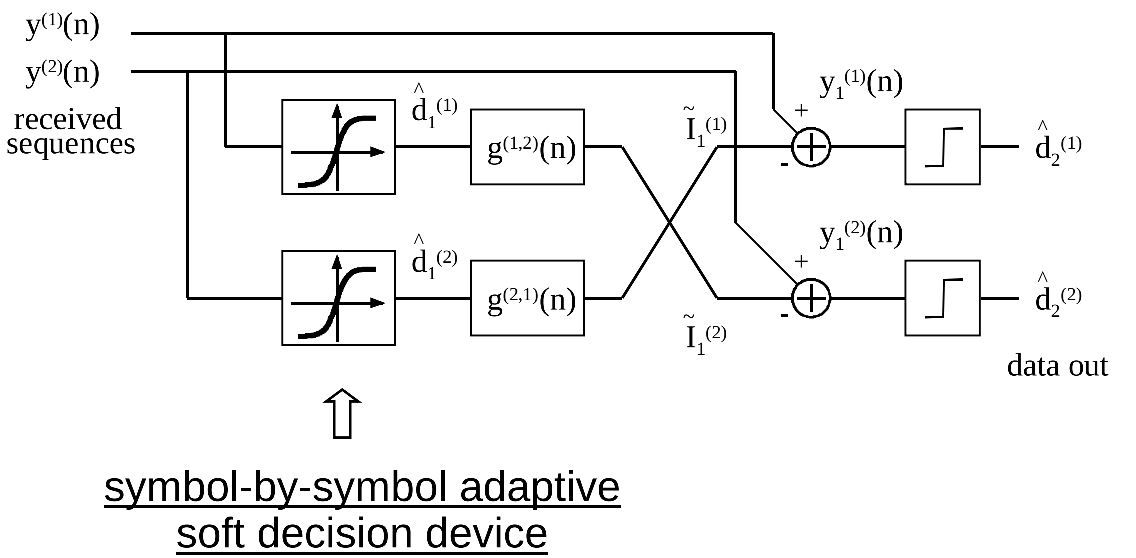
$$\tilde{d} = F[y] = \begin{cases} \tanh(\alpha y_R), & \text{if } abs(y_R) \geq abs(y_I) \\ j \cdot \tanh(\alpha y_I), & \text{if } abs(y_R) < abs(y_I) \end{cases}$$

  - where α is a scale factor and $y = y_R + j \cdot y_I = y^{(k)}(n)$

- multistage successive interference cancellation (MSIC) subtracts the interference with the most up-to-date symbol decisions

Multistage Bayesian (MB) interference cancellation

- MPIC/MSIC receiver with symbol-by-symbol adaptive soft decisions
  - for multipath channel and any complex modulation
- interference power estimate determines the scale factor of the non-linearity



Bayesian non-linearity

- Bayesian non-linearity:

magnitude:

$$\tilde{d} = E\{d \mid y\} == \frac{\sum_{m=0}^{M-1} (c_m + js_m) \exp\{\alpha (y_R c_m + y_I s_m)\}}{\sum_{m=0}^{M-1} \exp\{\alpha (y_R c_m + y_I s_m)\}}$$

  – $c_m + j \cdot s_m$, $m=0,\dots,M$ -1, are the constellation symbols

phase:

- the scale factor α is: $\alpha = 1/\sigma_{WI}^2 = 1/(\sigma_W^2 + \sigma_I^2)$
  – σ_I^2 is the variance of the sum of ISI and MAI
  – σ_W^2 is the variance of the observation noise $w^{(k)}(n)$

Estimate of the total interference

- for a practical measure of $\sigma_{WI}^2 = \sigma_W^2 + \sigma_I^2$, we employ symbol-by-symbol:

$$\sigma_{WI}^2 \approx \min_m \left\{ \left| y - g\left(c_m + j s_m\right) \right|^2 \right\}, \quad m = 0, \ldots, M-1$$

  – g is the main tap of S-CIR (typically real)

- using an averaged interference estimate gives worse performance
- hard-limiting ($\alpha = \infty$) is used for the last stage

Application to TDD-CDMA for UMTS

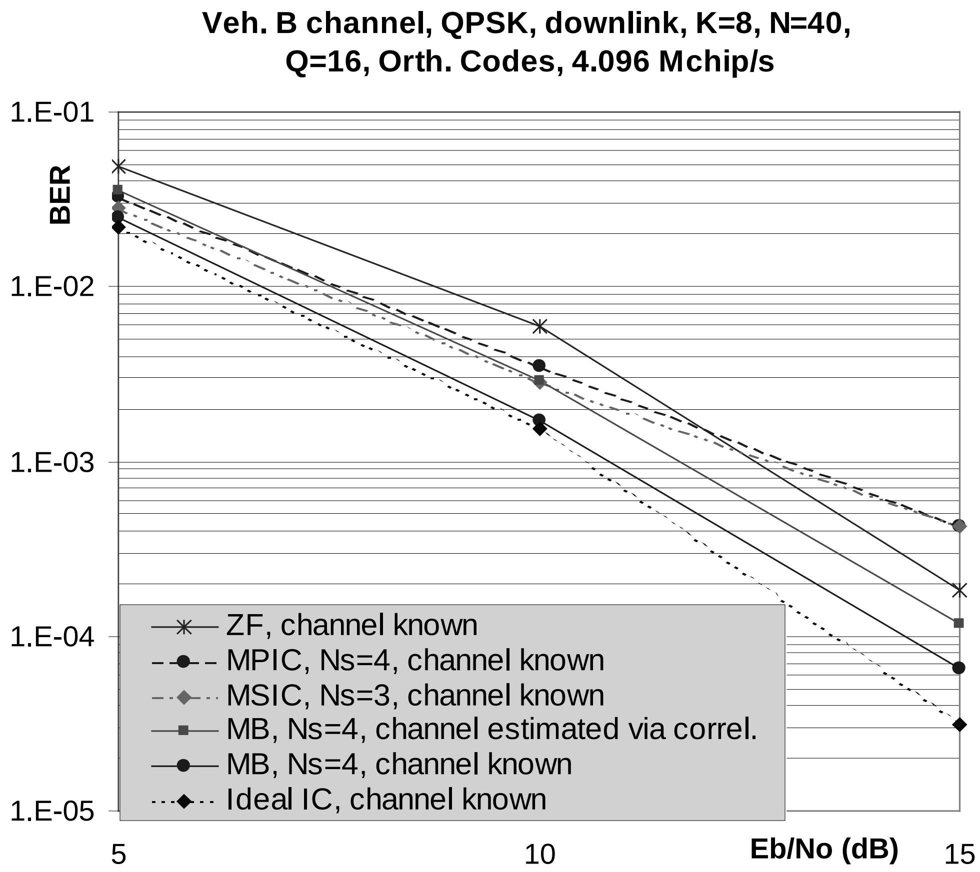
ETSI-SMG proposals for UMTS at the unified chip rate of 4.096 Mcps:
(*now changed to 3.84 Mcps*)

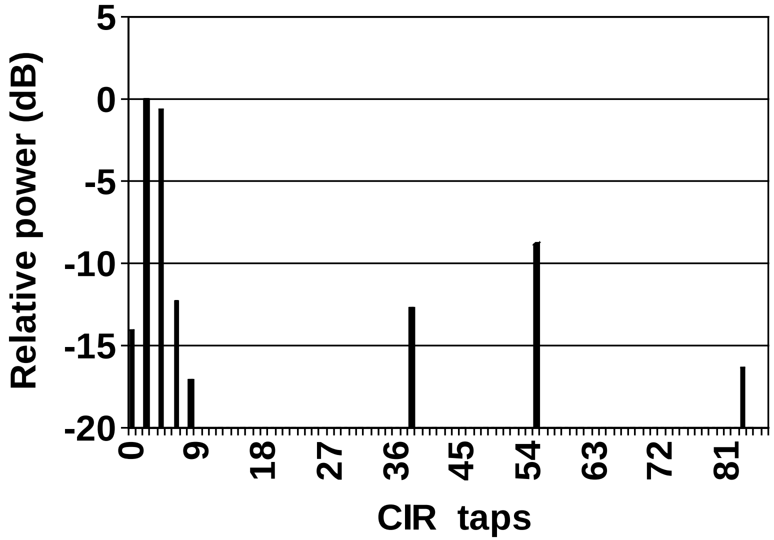
- Wideband W-CDMA (FDD) with spreading factors SF = 256,128,…,4
- **Time-Division TD-CDMA (TDD)** with:
  - small spreading factor SF=16
  - small number of simultaneously active users (max K=8)
  - multiplexing of users over 16 timeslots (*now 15*) on the same channel

User #1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1	2	...
User #2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1	2	...
………………………………																			
User #8	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1	2	...

time →

Vehicular B channel, TDD downlink

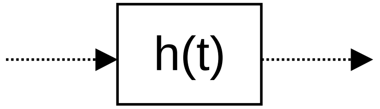




- modulation QPSK @4.096Mcps
- SF=16, Orthogonal Walsh codes
- 8 users, block length = 40

Channel Estimation for TDD downlink

- from signal theory: x(t)

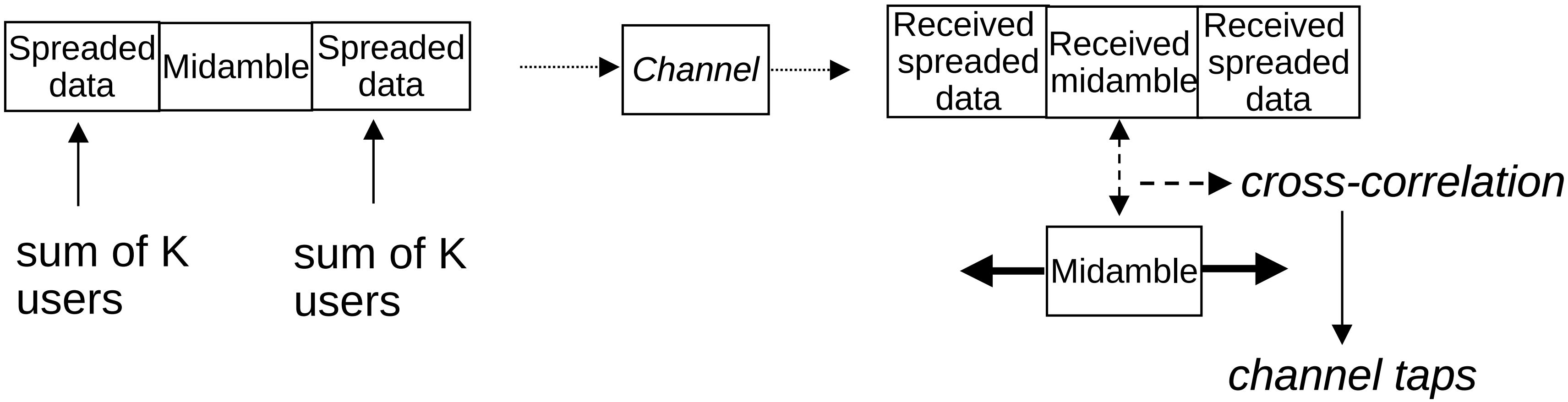


y(t)

$R_{xy}(\tau)=h(\tau)*R_{xx}(\tau)$

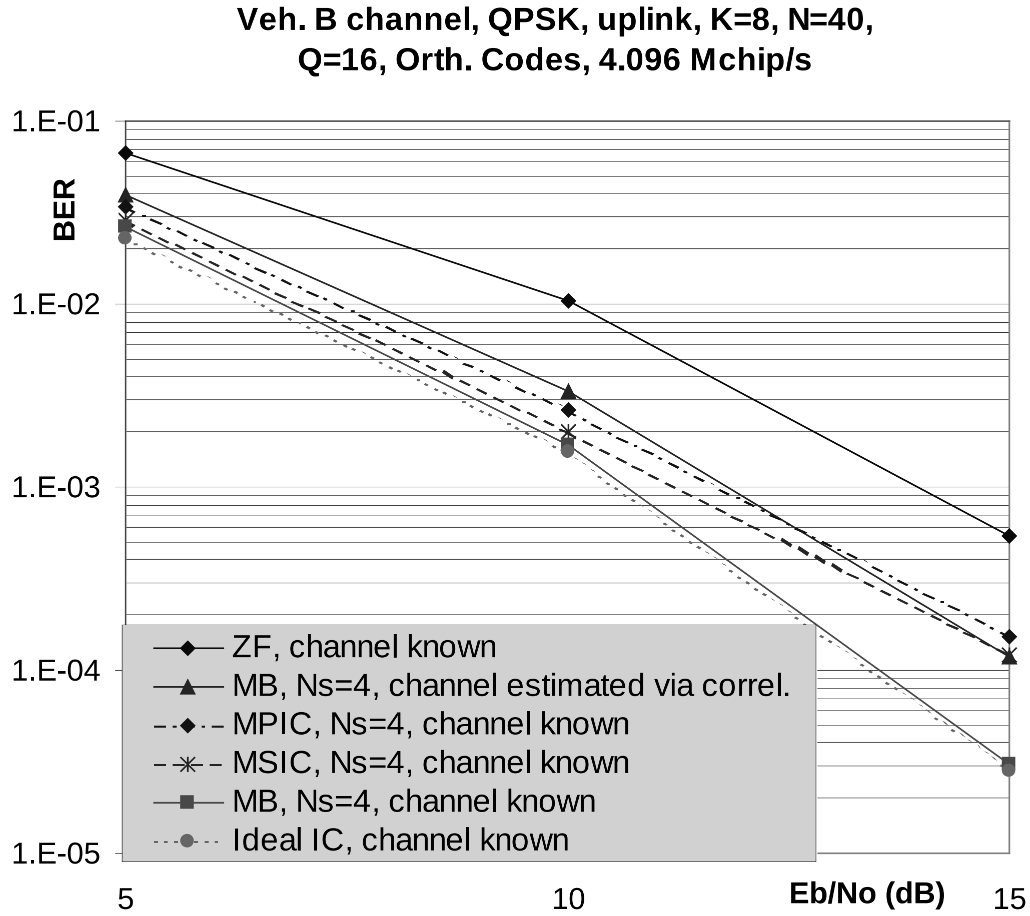
if $R_{xx}(\tau)=\delta(\tau)$, then $R_{xy}(\tau)=h(\tau)$

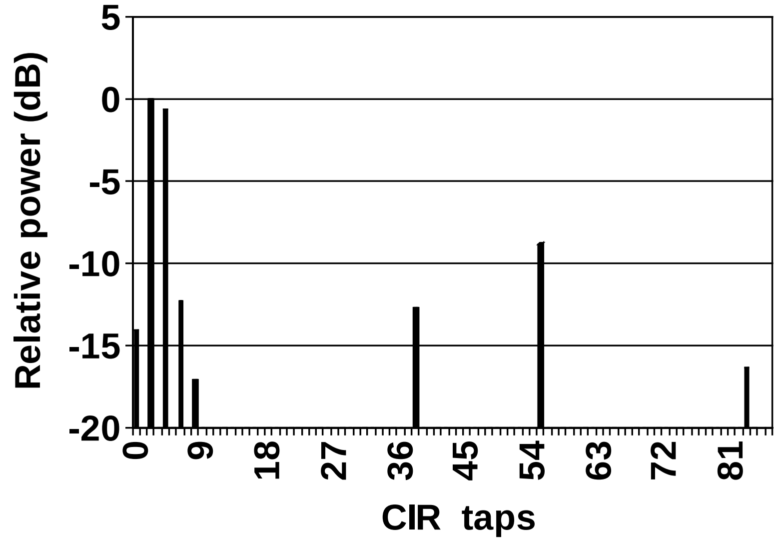
- channel estimation for downlink:



- the channel estimate is obtained by computing the cross-correlation between the (known) transmitted midamble and the received one

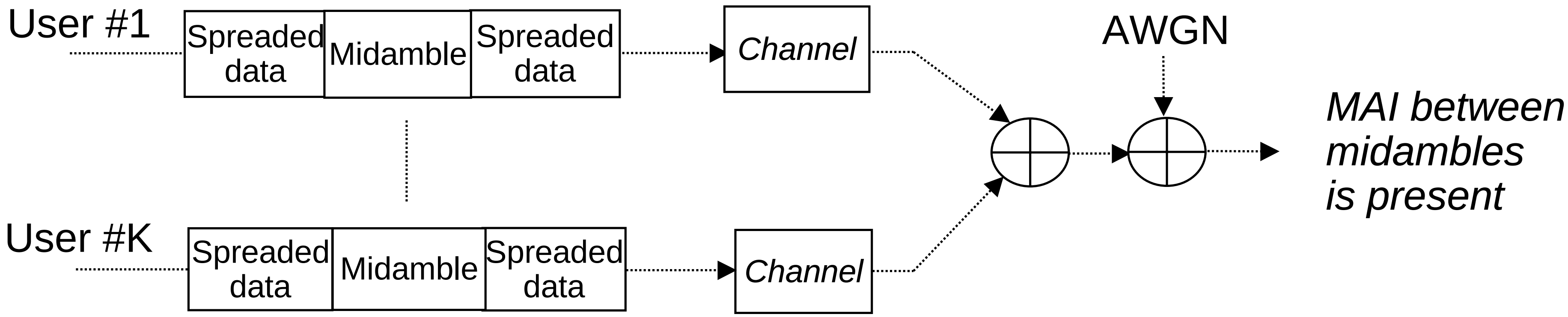
Vehicular B channel, TDD uplink





- modulation QPSK @4.096Mcps
- SF=16, Orthogonal Walsh codes
- 8 users, block length = 40

Channel Estimation for TDD uplink



Solution based on cross-correlation and multistage IC:

- for user #i, the cross-correlation method gives a "tentative" channel estimate
- other users regenerate the received midamble pertaining to user #i and subtract it from the received midamble before estimating (via cross-correlation) its own channel
- the procedure is repeated until that a satisfactory channel estimate is obtained for all users

Conclusions

We propose for multipath channel:

- MPIC detector with symbol-by-symbol MB interference cancellation
- MPIC detector with partial interference cancellation
- realistic channel estimation procedure for TDD-CDMA

– both detectors have approximately the same complexity

– MB-canceller has a performance close to the ideal cancellation with known channel and has a minor loss with realistic channel estimates

⇒ MB appears to be a good candidate for TDD and FDD receivers