Optimal Resource Allocation for CDMA Networks Based on Source Coders Adaptation with Application to MPEG4 FGS

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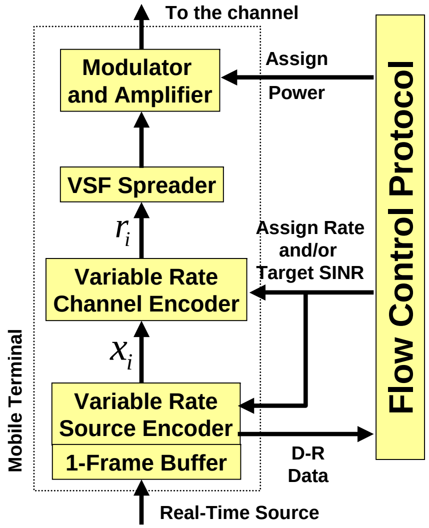
System Model



- N calls.
- Each user may be operating with a different source coder and with a D-R performance changing from frame to frame.
- Uplink, Single cell, DS-CDMA.
- Chip-sampled matched filter receiver.
- Ideal power control.
- Channel: AWGN.

CDMA Multiuser Power and Rate Allocation

- Target SINR: $\beta_i \geq \frac{W}{r_i} \frac{P_i}{\sigma^2 + \sum_{j \neq i} P_j}, \quad i = 1, \ldots, N$
- Let: $\Psi_i \triangleq \left(1 + \frac{W}{r_i \beta_i}\right)^{-1}$, then $P_i = \frac{\Psi_i \sigma^2}{1 - \sum_{j=1}^{N} \Psi_j}$

$$\Rightarrow \boxed{\sum_{i=1}^{N} \Psi_i \leq 1 - \varepsilon}$$

- **System stability / dynamic range condition.**

Flow Control and Resource Allocation

- With $b_i = (r_i, \beta_i)$, design problem is:

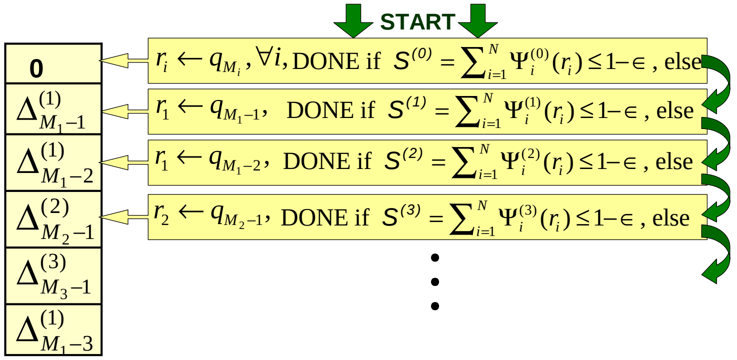
$$\min_{b_1, b_2, \ldots, b_N} \sum_{i=1}^{N} D_i(b_i) \quad \text{subject to} \sum_{i=1}^{N} \Psi_i(b_i) \leq 1 - \varepsilon$$

Allocation
Transmit rate
Target SINR
Distortion

- Solution to the problem of optimal adaptation of an arbitrary set of real-time source encoders to resolve interference-generated congestion.
- Solution can also be regarded as optimal source-controlled statistical multiplexing in CDMA.
- **Theorems:**
  1. $\exists \lambda \geq 0$ such that the solution $\mathrm{B}^*(\lambda)$ to the constrained problem
  $$\min_{B \in \mathbb{S}} H(B), \quad \text{subject to } R(B) \leq R_c$$
  is also the solution to the unconstrained problem
  $$\min_{B \in \mathbb{S}} \{ H(B) + \lambda R(B) \}$$
  with $R\left(B^*(\lambda)\right) = R_c$
  2. Let $D_i(b_i)$ and $\Psi_i(b_i)$ be real-valued functions. Also,
  $$b_i^*(\lambda_k) \triangleq \arg \min_{b_i \in \mathbb{S}^{(i)}} \{ D_i(b_i) + \lambda_k \Psi_i(b_i) \}$$
  If $\lambda_2 \geq \lambda_1 > 0$ then $\Psi_i\left(b_i^*(\lambda_2)\right) \leq \Psi_i\left(b_i^*(\lambda_1)\right)$, and $R^*(\lambda_2) \leq R^*(\lambda_1)$

Algorithm I: Adapt Transmit Bit Rate

- Optimal for D-R functions convex and decreasing.
- ith. incremental distortion associated with call j: $\Delta_i^{(j)} = D_j(q_{i+1}) - D_j(q_i)$



$r_i \leftarrow q_{M_i}, \forall i,$ DONE if $S^{(0)} = \sum_{i=1}^{N} \Psi_i^{(0)}(r_i) \leq 1 - \epsilon$, else

$r_1 \leftarrow q_{M_1-1},$ DONE if $S^{(1)} = \sum_{i=1}^{N} \Psi_i^{(1)}(r_i) \leq 1 - \epsilon$, else

$r_1 \leftarrow q_{M_1-2},$ DONE if $S^{(2)} = \sum_{i=1}^{N} \Psi_i^{(2)}(r_i) \leq 1 - \epsilon$, else

$r_2 \leftarrow q_{M_2-1},$ DONE if $S^{(3)} = \sum_{i=1}^{N} \Psi_i^{(3)}(r_i) \leq 1 - \epsilon$, else

⋮

Algorithm II: Adapt Transmit Bit Rate and Target SINR

- Let, at step j, $S^{(j)} = \sum_{i=1}^{N} \Psi_i^{(j)}(r_i)$

1. Initialize $\lambda^{(0)}$ with some positive number and iteration counter m=0.
2. Iteration m:
   - a. Find $b_i^*(\lambda^{(m)}), \forall i$, by solving $\min_{b_i \in \mathbb{S}^{(i)}} \{ D_i(b_i) + \lambda^{(m)} \Psi_i(b_i) \}$
   - b. Update $S^{(m)}$
   - c. If $S^{(m)} > 1 - \varepsilon$, update $\lambda^{(m+1)}$ such that $\lambda^{(m+1)} > \lambda^{(m)}$
   - d. If $S^{(m)} < 1 - \varepsilon$, update $\lambda^{(m+1)}$ such that $\lambda^{(m+1)} < \lambda^{(m)}$
   - e. STOP if
     - $S^{(m)}$ is sufficiently close but less than $1 - \varepsilon$.
     - $S^{(m)} < 1 - \varepsilon$ and all allocations corresponds to target minimum distortion.
     - $S^{(m)} > 1 - \varepsilon$ and all allocations corresponds to maximum allowable distortion.

Simulation Results

- Sequences: 40 % “Foreman” and 60 % “Akiyo”, 30 fps.
- Source Coder: MPEG4 FGS + error resiliency and concealment.
- Channel Coder: RCPC, K=9.