# FORMULAZIONE COMPLETA

VARIABLES: $X_{pq}^i$ → NODE $i$ USED FOR VNF $q$
ON SFC $p$

$B$ → BANDWIDTH     $D$ → DELAY

$R^w$ → NODE RESOURCE $w$

## MINIMIZE:

$$COST = \sum_i \sum_p \sum_{\substack{q \\ q \neq q_{LAST} \\ q \neq q_{INIT}}} \sum_w X_{pq}^i \cdot R_{pq}^w \cdot C_i^w \; + \qquad \# \; NODES$$

$$+ \sum_i \sum_{\substack{j \\ i \neq j}} \sum_p \sum_{\substack{q \\ q \neq q_{LAST}}} X_{pq}^i \cdot X_{pq+1}^j \; B_p \cdot C_{ij} \qquad \# \; LINKS$$

$$+ \sum_p \sum_q C_{pq} \; \boxed{?} \qquad \# \; \substack{EMBEDDING \\ COST}$$

## CONSTRAINTS

1) $\forall i \quad \sum_p \sum_{\substack{q \\ q \neq q_{LAST} \\ q \neq q_{INIT}}} \sum_w X_{pq}^i R_{pq}^w \leq MAX(R_i^w) \quad \# \; NODE \; RES$

2) $\forall i,j \mid i \neq j \quad \sum_p \sum_{\substack{q \\ q \neq q_{LAST}}} X_{pq}^i X_{pq+1}^j B_p \leq MAX(B_{ij}) \; \# \; \substack{LINK \\ BW}$

3) $\forall p \quad \sum_i \sum_j \sum_{\substack{q \\ q \neq q_{LAST}}} X_{pq}^i X_{pq+1}^j \cdot D_{ij} \leq D_p \quad \# \; LINK. \; DELAY$

4) $\forall p,q \quad \sum_i X_{pq}^i = 1 \qquad \# \; ONE \; NODE \; FOR \; EVERY \; FUNCTION$

5) $\forall p \quad \sum_q \sum_i \sum_j X_{pq}^i X_{pq+1}^j = LEN(p) - 1 \quad \substack{ALL \; LINKS \; OF \\ CHAIN \; ARE \; PRESENT}$
$i \neq j$

6) $\forall_{P,q} \quad \sum_i^k \sum_j^k x'_{pq} x'_{pq+1} = 1$

## NOTES

1) $B_{ij} = 0$ IF $ij$ NOT CONNECTED

2) $D_{ij} \to \infty$ IF $ij$ NOT CONNECTED

QUADRATIC DISEQUATIONS CANNOT BE EXPRESSED AS QUBO !!!

# FORMULAZIONE INCOMPLETA (LINK BASED)

**VARIABLES:** $y_{pq}^{ij}$ → LINK $ij$ IS USED FOR GOING FROM VNF $q$ TO $q+1$

$B$ → BANDWIDTH $\qquad$ $D$ → DELAY

$R^w$ → NODE RESOURCE $w$

## MINIMIZE:

→ CONSTANT PER NODO DI UN BECO RAND

$$\text{COST} = \sum_{i} \sum_{j < i} \sum_{p} \sum_{\substack{q \\ q \neq q_{init} \\ q \neq q_{last}}} \sum_{w} y_{pq}^{ij} \cdot R_{pq}^{w} \cdot C_{i}^{w} \quad + \qquad \text{\# NODES}$$

$$+ \sum_{i} \sum_{j} \sum_{p} \sum_{\substack{q \\ i < j \quad q \neq q_{last}}} y_{pq}^{ij} \cdot B_p \, C_{ij} \qquad \text{\# LINKS}$$

$$+ \sum_{p} \sum_{q} C_{pq} \boxed{?} \qquad \text{\# ONBOARDING COST}$$

## CONSTRAINTS

1) $\forall i: \quad \sum_{j} \sum_{p} \sum_{\substack{q \\ q \neq q_{init} \\ q \neq q_{last}}} \sum_{w} y_{pq}^{ij} R_{pq}^{w} \leq \text{MAX}(R_{i}^{w}) \qquad \text{\# NODE RES}$

2) $\forall i, j \mid i < j \quad \sum_{p} \sum_{\substack{q \\ q \neq q_{last}}} y_{pq}^{ij} B_p \leq \text{MAX}(B_{ij}) \quad \text{\# LINK BW}$

3) $\forall p \quad \sum_{i} \sum_{j < i} \sum_{\substack{q \\ q \neq q_{last}}} y_{pq}^{ij} D_{ij} \leq D_p \qquad \text{\# LINK DELAY}$

4) $\forall p, q \atop q \neq q_{init} \atop q \neq q_{last} \quad \sum_{i} \sum_{j < i} y_{pq}^{ij} = 1 \qquad \text{\# ONE NODE FOR EVERY FUNCTION}$

5) $\forall p \quad \sum_{q} \sum_{i} \sum_{j < i} y_{pq}^{ij} = \text{LEN}(p) - 1 \qquad \text{ALL LINKS OF CHAIN ARE PROCESSED}$
$q \neq q_{last}$

6) $\forall p, q$ at quasr $\sum_i \sum_j Y_{pq}^{ij} = 1$   ONLY ONE LINK BETWEEN TWO VNFz