FORMULAZIONE COMPLETA

VARIABILI: X^i_{pq} → NODE i USED FOR VNF q ON SFC p

B → BANDWIDTH D → DELAY

R^w → NODE RESOURCE w

MINIMIZE:

$$\text{COST} = \sum_{i}\sum_{p}\sum_{q}\sum_{w} X^i_{pq} \cdot R^w_{pq} \cdot C^w_i + \quad \#\ \text{NODES}$$
$$q \neq q_{last},\ q \neq q_{init}$$

$$+ \sum_{i}\sum_{j}\sum_{p}\sum_{q} X^i_{pq} \cdot X^j_{pq+1} B_p \cdot C_{ij} \quad \#\ \text{LINKS}$$
$$i \neq j \qquad q \neq q_{last}$$

$$+ \sum_{p}\sum_{q} C_{pq} \quad (?) \qquad \#\ \text{EMBEDDING COST}$$

CONSTRAINTS

1) $\forall i \quad \sum_{p}\sum_{q}\sum_{w} X^i_{pq} R^w_{pq} \leq \text{MAX}(R^w_i)$ # NODE CAPS
$q \neq q_{last}, q \neq q_{init}$

2) $\forall i,j \mid i \neq j \quad \sum_{p}\sum_{q} X^i_{pq} X^j_{pq+1} B_p \leq \text{MAX}(B_{ij})$ # LINK BW
$q \neq q_{last}$

3) $\forall p \quad \sum_{i}\sum_{j}\sum_{q} X^i_{pq} X^j_{pq+1} D_{ij} \leq D_p$ # LINK DELAY
$i \neq j \qquad q \neq q_{last}$

4) $\forall p,q \quad \sum_i X^i_{pq} = 1$ # ONE NODE FOR EVERY FUNCTION

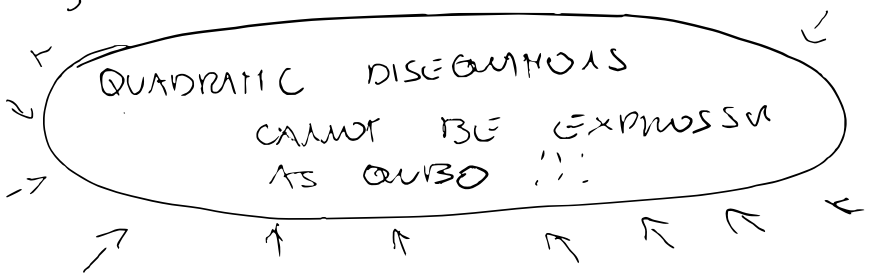
5) $\forall p \quad \sum_{q}\sum_{i}\sum_{j} X^i_{pq} X^j_{pq+1} = \text{LEN}(p) - 1$ ALL LINKS OF CHAIN ARE PROCESSED
$i \neq j$

6) $\forall_{p,q}$ $\sum_{i} \sum_{j \neq i} x'_{pq} x'_{p(q+1)} = 1$

NOTES

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

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



FORMULAZIONE INCOMPLETA (LINK BASED)

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

B_i → BANDWIDTH D_i → DELAY

R_i^w → NODE RESOURCE w

MINIMIZE:

$$\text{COST} = \sum_{i}\sum_{j\neq i}\sum_{p}\sum_{q\neq \text{lastVNF}}\sum_{w} y_{pq}^{ij} \cdot R_{pq}^{w} \cdot C_j^w + \quad \text{\# NODES}$$

(C_j^w → CONSUMO PER NODO DI UN DATO TIPO)

$$+ \sum_{i}\sum_{j\neq i}\sum_{p}\sum_{q\neq \text{lastVNF}} y_{pq}^{ij} \cdot B_p C_{ij} \quad \text{\# LINKS}$$

$$+ \sum_{p}\sum_{q} C_{pq} \quad (?) \quad \text{\# EMBEDDING COST}$$

CONSTRAINTS

1) $\forall_{i,w}\ \sum_{j\neq i}\sum_{p}\sum_{q\neq \text{lastVNF}} y_{pq}^{ij} R_{pq}^{w} \leq \text{MAX}(R_i^w)$ \# NODE RES

2) $\forall_{i,j \mid i\neq j}\ \sum_{p}\sum_{q\neq \text{lastVNF}} y_{pq}^{ij} B_p \leq \text{MAX}(B_{ij})$ \# LINK BW

3) $\forall_p\ \sum_{i}\sum_{j\neq i}\sum_{q\neq \text{lastVNF}} y_{pq}^{ij} D_{ij} \leq D_p$ \# LINK DELAY

4) $\forall_{p,q\neq \text{lastVNF}}\ \sum_{i}\sum_{j\neq i} y_{pq}^{ij} = 1$ \# ONE NODE FOR EVERY FUNCTION

5) $\forall_p\ \sum_{q\neq \text{lastVNF}}\sum_{i}\sum_{j\neq i} y_{pq}^{ij} = \text{LEN}(p) - 1$ ALL LINKS OF CHAIN ARE DIFFERENT

6) $\forall p,q$ $\sum_i \sum_j y_{pq}^{ij} = 1$ ONLY ONE LINK BETWEEN TWO VERTICES
$q \neq q_{ST}$ $i \neq j$

NOTES

- CONDIZIONE 5) NON FORZA UNA DELLA STESSA CLIQUE AD ESSERE COMPLETA !!

↳ DIFFICILE AGGIUNGERE COME CONSTRAINT CHE SIA QUADRATICO

LINK FORMULATION (NEW)

VARIABLES

L_{pq}^{ij} → LINK $i \to j$ IS USED FOR VNF CONNECTION $q \to q+1$ OF CHAIN p

q_0 → FAKE FUNCTION ASSIGNED TO ENTRY NODE

q_L → FAKE FUNCTION ASSIGNED TO EXIT NODE

↳ $L_{pq_L}^{ij}$ DOES NOT NOT

B → BANDWIDTH

R^w → NODE RESOURCE w

D → DELAY

C^w → UNIT COST OF RESOURCE w

$T(i) \mid i \in NODES \to \{ SERVER, ENTRY, EXIT \}$

MINIMIZE:

$$COST = \sum_{\substack{i \\ i \neq j}} \sum_{j} \sum_{p} \sum_{\substack{q \\ T(i)=SERV. \\ T(j)=SERV.}} \sum_{\substack{w \\ q \neq q_0 \\ q=q_L}} L_{pq}^{ij} \cdot R_{pq}^{w} \cdot C_{j}^{w} \quad \# \text{ NODE COST}$$

$$+ \sum_{\substack{i \\ i \neq j}} \sum_{j} \sum_{p} \sum_{\substack{q \\ q \neq q_L}} L_{pq}^{ij} \cdot B_p C_{ij} \quad \# \text{ LINK COST}$$

$$+ \sum_{p} \varepsilon_q C_{pq} \to \text{DOES NOT MATTER FOR QUBO} \quad \# \text{ EMBEDDING COST}$$

CONSTRAINTS

1) $\forall_{i,w} \sum_{j} \sum_{p} \sum_{q} L^{ij}_{pq} R^{w}_{pq} \leq MAX(R^{w}_{i})$ # NODE RES

$T(i)$ = serv. $T(j)$ = serv. $i \neq j$ $q \neq q_0$ $q \neq q_L$

2) $\forall_{i,j \mid i \neq j} \sum_{p} \sum_{q} L^{ij}_{pq} B_p \leq MAX(B_{ij})$ # LINK BANDWIDTH

$q \neq q_L$

3) $\forall_p \sum_{i} \sum_{j} \sum_{q} L^{ij}_{pq} D_{ij} \leq D_p$ # LINK DELAY

$i \neq j$ $q \neq q_L$

4) $\forall_{p,q} \sum_{i} \sum_{j} L^{ij}_{pq} = 1$ # EXACTLY ONE LINK FOR EVERY $q \to q+1$

$q \neq q_L$

5) $\forall_p \sum_{q} \sum_{i} \sum_{j} L^{ij}_{pq} = LEN(p) - 1$ # LENGTH OF CHAIN IS FIXED

$q = q_L$ $i \neq j$

6) $\forall_{j,p,q} \sum_{i} L^{ij}_{pq} - \sum_{k} L^{jk}_{pq+1} = 0$ # CONTINUITY AND ORDER OF VNF LINKS.

$T(j) = serv.$ $q \neq q_L$

COMMONS

A) IF BOTH $i \neq j$ CONSTRAINTS MAYBE YOU CAN PUT CONSECUTIVE VNF_n ON SAME NODE

B) L_{pq}^{ij} WITHOUT $type(i) = ONLY$ ($type(j) = EXIT$) AND $q \neq q_0$ ($q \neq q_{L-1}$) DOES NOT EXIST

LINK FORMULATION ($|N|W^2$)

VARIABLES

L_{pq}^{ij} → LINK $i \to j$ IS USED FOR VNF CONNECTION $q \to q+1$ OF CHAIN p

q_0 → FIRST VNF OF CHAIN

q_L → LAST VNF OF CHAIN

B → BANDWIDTH

R^w → NODE RESOURCE w

D → DELAY

C^w → UNIT COST OF RESOURCE w

$$\delta_{sol}(q) = \begin{cases} 1 \text{ IF } q = q_{L-1} \\ 0 \text{ IF } q \neq q_{L-1} \end{cases}$$

MINIMIZE:

$$COST = \sum_{\substack{i \\ i \neq j}} \sum_{j} \sum_{p} \sum_{q} \sum_{w} L_{pq}^{ij} \cdot R_{pq}^{w} \cdot \left(C_i^w + C_j^w \delta_{sol}(q) \right)$$

$q \neq q_{last}$; # NODE COST

$$+ \sum_{\substack{i \\ i \neq j}} \sum_{j} \sum_{p} \sum_{q} L_{pq}^{ij} \cdot B_p C_{ij}$$

$q \neq q_L$; # LINK COST

$$+ \sum_{p} \varepsilon_q C_{pq}$$

→ DOES NOT MATTER FOR OURS ; # EMBEDDING COST

CONSTRAINTS

1) $\forall_{i,w} \sum_{j \neq i} \sum_{p} \sum_{q \neq q_L} L_{pq}^{ij} \left(R_{pq}^{w} + R_{pq_L}^{w} \delta_{sd_L}(q) \right) \leq MAX\{R_i^w\}$

NODE RES

2) $\forall_{i,j | i<j} \sum_{p} \sum_{q \neq q_L} L_{pq}^{ij} B_p + L^{ji} B_p \leq MAX(B_{ij})$

LINK BANDWIDTH

3) $\forall_p \sum_{i \neq j} \sum_{q \neq q_L} L_{pq}^{ij} D_{ij} \leq D_p$ # LINK DELAY

4) $\forall_{p,q \neq q_L} \sum_{i} \sum_{j \neq i} L_{pq}^{ij} = 1$ # EXACTLY ONE LINK FOR EVERY $q \to q+1$

5) $\forall_p \sum_{q \neq q_L} \sum_{i} \sum_{j \neq i} L_{pq}^{ij} = LEN(p) - 1$ # LENGTH OF CHAIN IS FIXED

6) $\forall_{j,p,q \neq q_L} \sum_{i} L_{pq}^{ij} - \sum_{k} L_{pq+1}^{jk} = 0$ # CONTINUITY AND ORDER OF VNF LINKS.

7) $\forall_{i,j,p \neq i} \sum_{q \neq q_L} L_{pq}^{ij} \leq 1$ # TWO VNF OF SAME CHAIN CANNOT BE ON SAME NODE.

COMMONS

A) IF NONE $i \neq j$ CONSTRAINTS MAYBE YOU CAN PUT CONSECUTIVE VAF_2 ON SAME NODE

B) YOU CAN FIX STARTING/ENDING POINT(S) OF VAF BY REMOVING POSSIBILITY OF NODE TO BE USED IN THE MIDDLE OF THE CHAIN

C) CONSTRAINT 7) IS ONLY NEEDED TO MAKE 6) WORK IF STARTING AND ENDING POINTS OF VAF_2 ARE NOT FIXED.