Mobility Aware Optimal Placement of Virtual Network Functions in 5G

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Abstract

Virtual Network Functions (VNFs) in cloud servers of 5G network systems are responsible for executing offloaded codes from mobile users. Placement of VNFs in the cloud is very complicated to get on-time service from the cloud due to users' mobility. Minimizing the number of VNF relocations and the communication delay are the two main design goals for VNF placement; however they do oppose each other. In this paper, we have developed an optimization framework to trade-off between the aforementioned parameters. Our performance analysis depicts that user satisfaction is improved significantly in our proposed system compared to state-of-the-art works.

Service Architecture of 5G

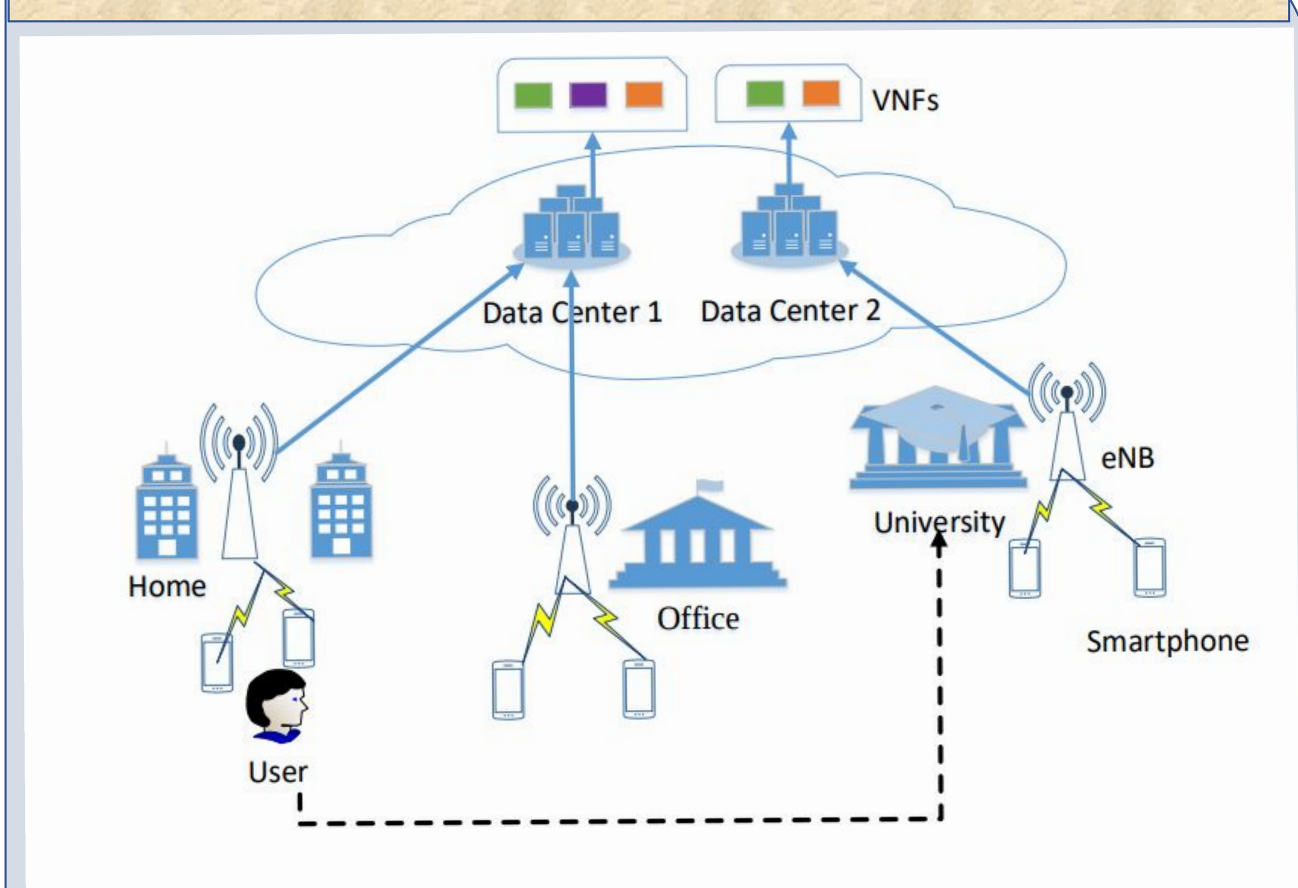


Fig 1: User Service Architecture in 5G

- Users of an eNB are served by VNFs of exactly one data center.
- associated eNBs of the home and university is connected to data center 1 and data center 2, respectively.
- When any user moves from his/her home to university, the placement of the running VNFs of that user becomes a matter of concern.

System Model

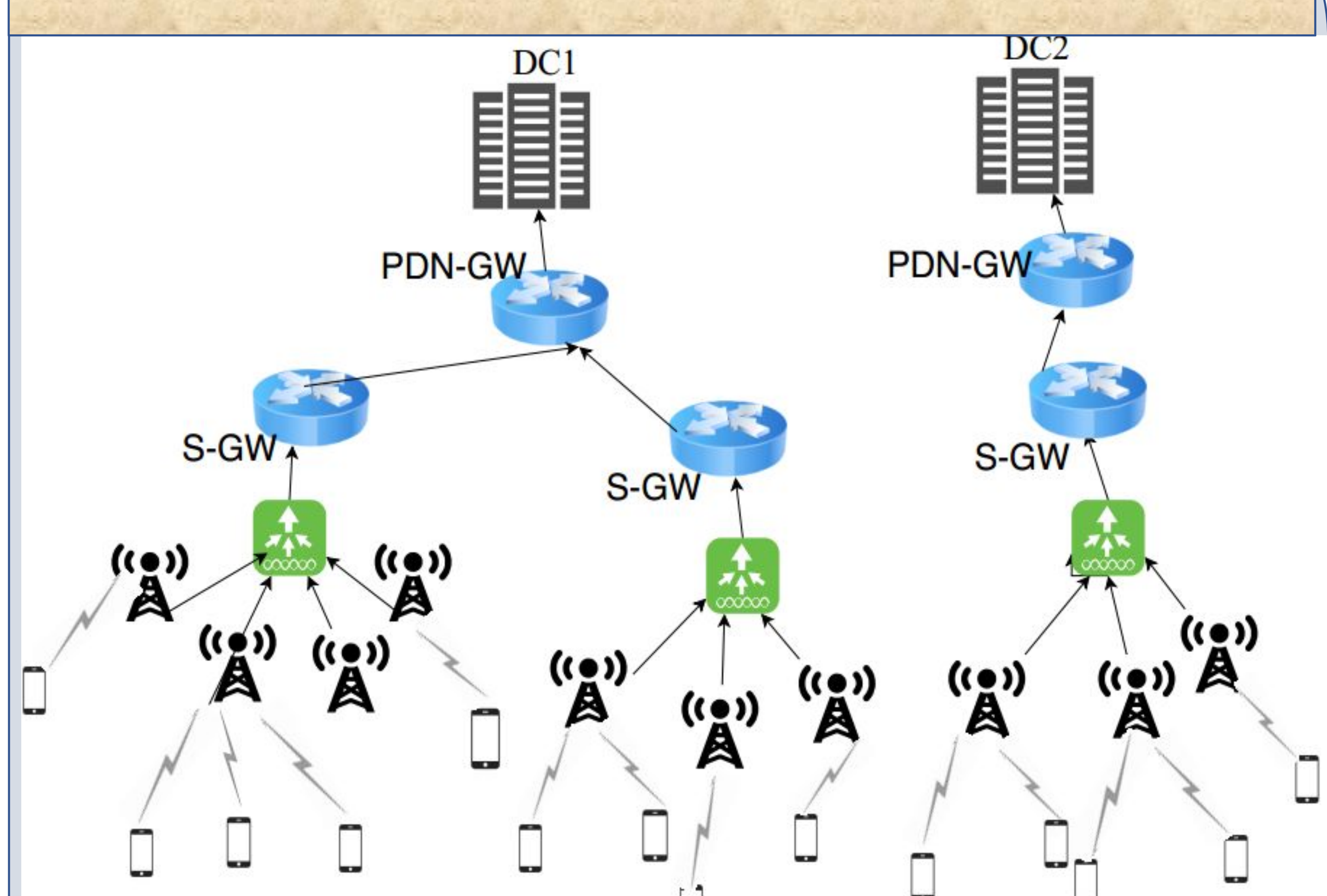


Fig 2: System Architecture of VNF services in 5G

Objectives

- Optimal Placement of Virtual Network Functions (VNFs) in the data centers (DCs)
- Maximizing Quality of Experience (QoE)
- Decreasing the cost of operation
- Trade off between minimizing VNF Relocation and response time

Relocation Time

$$R_{k,j}^f = \{(1-p_k^f) \times b_{k,j}^f\} \times H_k^f$$

$$H_k^f = (1-n_k^f) \times \tau_f$$

$$\tau_f = \frac{S_f}{r}$$

Response Time

$$C_{k,j}^f = b_{k,j}^f \times (t_j + t_k)$$

Objective Function

$$min \sum_{j\in N} \sum_{f\in V_j} \sum_{k\in D} \{\gamma \times R_{k,j}^f \times \phi_k + (1-\gamma) \times C_{k,j}^f \times \sigma_k\}$$

Constraints

1. Binary Constraint

$$b_{k,j}^f = \{0,1\}, \quad \forall j\in N, \quad \forall f \in V_j, \quad \forall k \in D$$

2. Atomicity Constraint

$$\sum_{k\in D} b_{k,j}^f = 1, \quad \forall j \in N, \quad \forall f \in V_j$$

3. VNF Allocation Constraint

$$\sum_{f\in V_j} \sum_{k\in D} b_{k,j}^f = |V_j|, \quad \forall j \in N$$

4. Application Deadline Constraint

$$\sum_{k\in D} (R_{k,j}^f + C_{k,j}^f + \varphi_f) \le \delta_{worst}, \quad \forall j \in N, \quad \forall f \in V_j$$

$$\varphi_f = \frac{I_f}{MIPS_k}, \forall k \in D$$

- 5. DC's Capacity Constraint

$$\sum_{j\in N} \sum_{f\in V_j} b_{k,j}^f \le \zeta^D, \quad \forall k \in D$$

Research Challenges

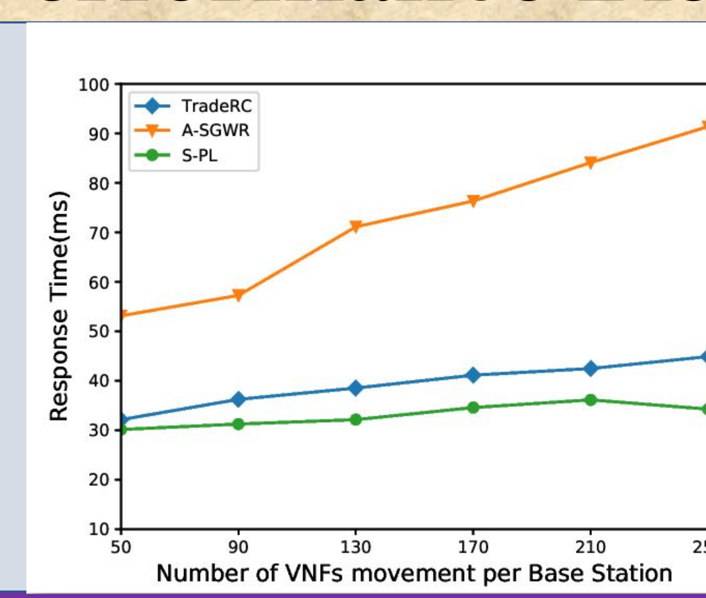
- Fixed resources allocation will not work
- Mobile devices have limited resources and limited energy
- Relocation incurs cost/delay

Simulation Environment

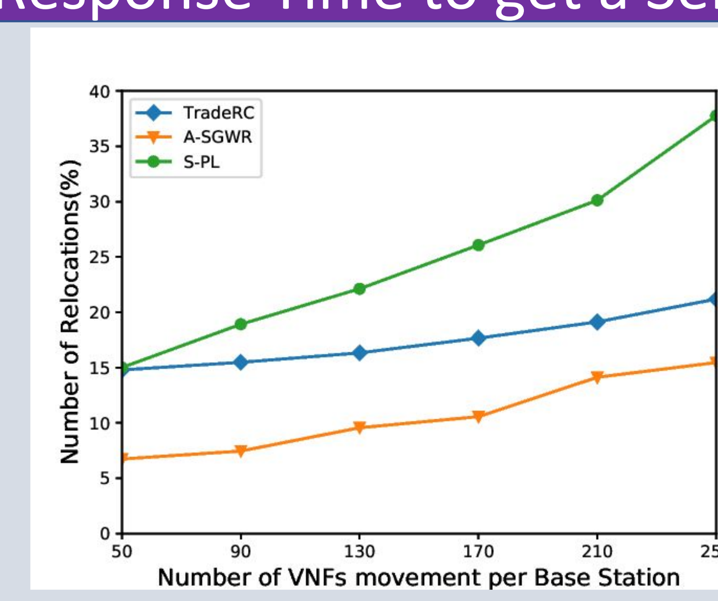
Simulated in NEOS optimization Server.

Parameter	Value
Simulation area	2000 ×2000 m^2
Number of Data-Centers (DC)	12
Number of Base Station under a DC	4 ~ 25
Number of VNFs under a BS	500 ~2000
Communication delay between DCs	10 ~200 msec
Communication delay between DC and BS	2 ~5 msec
Date rate to transfer VNF between DCs	1 ~50 Mbps
Weight factor (γ)	0.7

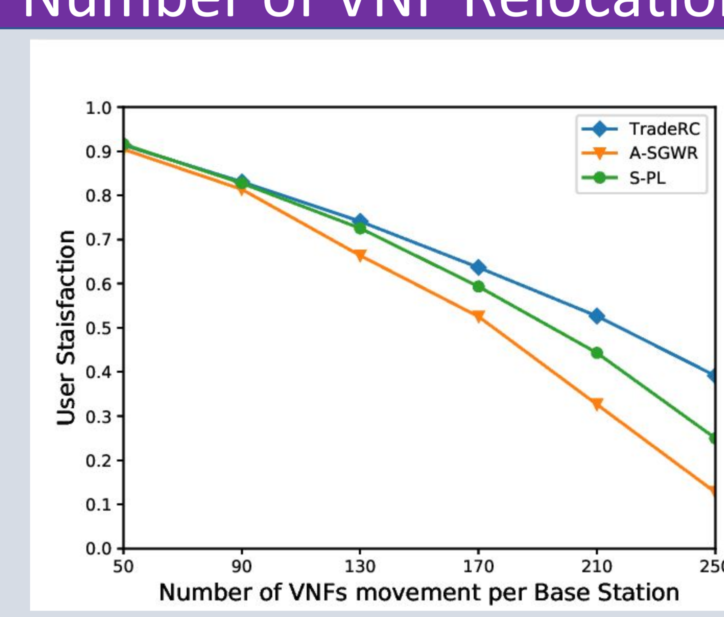
Performance Results



Response Time to get a Service



Number of VNF Relocation (%)



User Satisfaction

Conclusion & Future Work

- Optimal Placement of VNFs in DC.
- Trades-off between minimizing number of VNF relocation and total communication delay.
- Improves user satisfaction as high as 15%.
- Can't feasible for large networks due to non-polynomial execution time.
- Reduce time complexity using heuristic or meta heuristic based approaches.

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