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***Abstract*—In this work, we consider the 5G network architecture outcome of the Horizon 2020 project Superfluidity, where the main building blocks are virtual entities, namely Reusable Functional Blocks (RFBs). This 5G Superfluid network composed of RFBs and physical 5G nodes allows a high level of flexibility, agility, portability and high performance. The emergency problem we face is how to optimally minimize the total installation costs of such a Superfluid network while guaranteeing a minimum required user coverage and minimum downlink traffic demand. We propose an approach to break down the main resource allocation problem in a set of simplified problems that allow the computation of the solution in a more efficient way. Numerical results illustrate our findings.**

***Index Terms*—5G Superfluid wireless networks, Linear Programming**

I. Introduction

With the exponential rise of mobile users, overall mobile data traffic is expected to grow to 49 EBs (1EB = 10^6 GB) per month by 2021, a sevenfold increase over 2016 as pointed out in [1]. The current mobile wireless networks are not either able to manage such onerous traffic demands or fulfill other increased quality of service (QoS) requirements such as ultra low latency, massive number of connected devices. Fortunately, the forthcoming generation of wireless networks so-called 5G have been proposed to address these relevant issues, and are promised to support, among other things [2]:

- ubiquitous connectivity (many types of devices will connect ubiquitously and an uninterrupted connection will be perceived by users);
- zero latency (supporting life-critical systems, real-time applications, and services with zero delay tolerance);
- high-speed gigabyte connection (using a high-speed connection for fast data transmission and reception, i.e. at least 50 Mbps whenever).

To achieve this performance, lots of novel 5G architectures have been proposed. For example, Superfluidity [3], SelfNet [4], and Flexible Functional Split [5]. In this paper, we focus on 5G superfluid architecture as detailed in [3] where the main building blocks are virtual entities, namely Reusable Functional Blocks (RFBs). This 5G Superfluid network composed of RFBs and physical 5G nodes allows a high level of flexibility, agility, portability and high performance. The main question studied in this work is how to optimally minimize the total installation costs of such a Superfluid network while guaranteeing a minimum required user coverage and minimum downlink traffic demand.

a) State-of-Art: Let us first refer to [6], which proposes a mathematical model for the optimal management of RFBs in a 5G Superfluid network, to pursue either maximizing the user throughput or minimizing the number of used nodes. A Particle Swarm Optimization heuristic algorithm is then proposed to achieve its fast solution in [7] due to high complexity of problem involved in [6]. Furthermore, the work in [6] is tailored for the management phase, revolving network resources required by each RFB module. However, the cost design aspect is neglected, the incurred cost by network operators could be extremely high to meet the optimal management solution. Moreover, a user may receive a very low amount of downlink traffic in such a given solution. To the best of our knowledge, some work closely related to ours is [8], in which the authors have investigated optimal installation problem of such a 5G Superfluid network to address above issues. In particular, the optimal solution obtained during the design phase can be used as an input for the management one. However, the formulation given in [8] proposes several interdependent subproblems, which makes the associated constraints become nonlinear. Consequently, this leads to a large quantity of additional artificial variables and linearized constraints added into the original formulation. We propose to break down this combination by separating all components in a chain of RFBs to its own allocation subproblems in order to simplify problem structure and reduce its computational time on solving.

b) Contribution: Specifically, our original contributions can be summarized as follows:

- we propose an alternative mathematical formulation for the problem of minimizing the installation costs of a 5G Superfluid network via a new modeling way to represent the associated capacity constraints. Furthermore, we show that subset of constraints in the model can be replaced by a reduced number of simplified constraints;
- we test the model on realistic instances showing that the alternative simplified model can achieve drastic reduction in computational time while ensuring a high QoS to users.

The rest of the paper is organized as follows. After this introduction, in Section II we report a short discussion on Superfluid 5G architecture. In Section III, we present the linear programming based model and its simplified version. In section IV, the computational results illustrate the efficiency of our model. Finally, a conclusion is given in Section V.

II. Superfluid 5G Architecture

We report here a brief overview of the Superfluid 5G architecture detailed in [3], whose main building blocks are RFBs. The RFB concept is a generalization of Virtual Network Function entity. It can be mapped into different software and hardware execution environments in order to support allocation and deallocation on the 5G nodes. It can also be arbitrarily decomposed in other RFBs, thus realizing less complex and/or recursive functions. Within these features, RFBs are shared among the nodes, and deployed only where and when they are really needed in order to provide an agile and flexible service to users. Specifically, an RFB performs specific tasks in the network architecture, such as processing the video to users, or performing networking and physical layer tasks [6]. Focusing on the tasks realized on RFBs, following RFB types are taken into consideration:

- Resource Radio Head RFB (RRH RFB): it is in charge of providing physical signal to users. Specifically, it handles a set of Radio Frequency (RF) channels with users and the corresponding baseband channels with BBU RFBs;
- Base Band Unit RFB (BBU RFB): it acts as a middle interface between RRH RFBs and MEC RFBs. Specifically, BBU RFB exchanges an amount of IP traffic with MEC RFBs, and a baseband signal with RRH RFBs;
- Mobile/Multi-access Edge Computing RFB (MEC RFB): it is able to serve an amount of traffic, such as the provisioning of a HD (High Definition) video service to users.

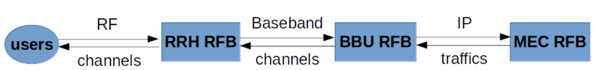

Fig. 1: A complete chain of RFBs serving users

We assume that a 5G node can provide a service to user if and only if there exists a complete chain of RFBs composed of one RRH RFB, one BBU RFB and one MEC RFB. The components of such a chain are linked to each other in this order as shown in Fig.1. Furthermore, they are not constrained to be located on the same 5G node, it can also be realized across several nodes. One thing that should be known is that each 5G node is able to host at most one RRH RFB, one BBU RFB and one MEC RFB. Specially, in resource consummation, a user will occupy a couple of radio-links managed by an RRH RFB installed on an activated 5G node, and will also produce some IP traffics managed by MEC RFBs. For what concerns BBU RFBs, it is served as a bridge connecting RRH RFBs and MEC RFBs, and is supposed to have an unbounded capacity to transfer traffics over the chain of RFBs in this paper. The requirements in terms of consumed resources by users are then used in this work to properly dimension the 5G nodes. Finally, we consider an additional classification of each RFB task based on its type. More precisely, a Micro and a Macro RFB depending on the capacity of the number of served users and the covered area are considered in our model.

III. Mathematical Formulation

A. Motivation

We recall that our problem is firstly studied in [8] where it has been presented as composed of three parts: A) User-Node Assignment problem; B) Node-RRH Allocation problem; C) Chain of RFBs Construction problem via RRH-BBU and RRH-MEC sub-chains generation, and its capacity constraints for each RFB module (especially involved in RRH RFBs and MEC RFBs). A very high combination is hence exhibited in a service/data link from a user finally to a MEC RFB due to the connection among User-Node, Node-RRH and RRH-MEC subproblems. More in depth, we observe that BBU RFBs installation totally depends on RRH RFBs installations, and MEC RFBs installation depends both on RRH RFBs installation and its capacity constraint in terms of traffic. We propose hereby to break down this combination by separating all components in a chain of RFBs to its own allocation subproblems. We connect a BBU RFB to a 5G node directly rather than via an RRH RFB. Secondly, RRH-MEC allocation is represented by a Node-MEC and User-Node-MEC subproblems as presented in Fig.2, where the latter can be absorbed by the former via a reduced number of constraints as shown in Section III-D. Therefore, the capacity constraints in terms of traffic for MEC RFBs are then solved implicitly. Moreover, one thing noticed here is that a chain of RFBs is implicitly deduced by the Node-RRH, Node-BBU and Node-MEC assignment solution.

B. Notation

Below in Table I and II, we report the parameters and variables used in our model.

TABLE I: Input parameters

Name	Description
U	the set of users, $\|U\|$ indicates the number of users.
N	the set of 5G nodes.
K	the set of RFB modules (i.e., RRH RFBs, BBU RFBs, MEC RFBs).
Q	the set of type for a chain of RFBs or RFB modules (i.e., Micro, Macro).
A_q^k	the available number of each RFB module k over the network of type q.
$\mathrm{U}_q^{\max}$	the max number of served users by an RRH RFB of type q.
α	the min fraction of user coverage, bounded in [0,1].
β_q	the conflict set of all pairs of 5G nodes for RRH RFBs of type q.
δ_{unq}	the max radio-link capacity provided to a user u at a 5G node n installed an RRH RFB of type q.
δ_q^{RRH}	the max total radio-link capacity managed by an RRH RFB of type q.
δ_q^{MEC}	the max total traffic managed by a MEC RFB of type q.
c_q^k	the installation cost of each activated RFB module k of type q.
c_q^{RFBC}	the installation cost for a chain of RFBs of type q.
t_{M}	the minimum required traffic by users.

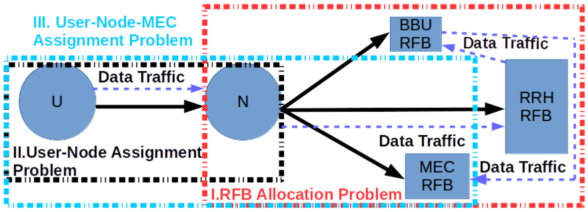

Fig. 2: New proposed structure of concerned problem

TABLE II: Decision variables

Name	Description
t_u	the downlink traffic of user u.
x^k_{nq}	1, if an RFB module k is placed on a 5G node n serving a chain of RFBs of type q; 0, otherwise.
y_{un}	1, if a user u is served by a 5G node n placed with RRH RFBs; 0, otherwise.
z^{MEC}_{unq}	1, if a user u is served by a 5G node n installed a MEC RFB of type q; 0, otherwise.
θ_{unq}	a product of y_{un} and x^{RRH}_{nq}.
t_{unq}	a product of z^{MEC}_{unq} and t_u.

C. Mathematical Formulation

Using the notations presented in Table I and II, we give below the compact mathematical formulation of our problem:

$$\textbf{min} \sum_{n\in N}\sum_{k\in K}\sum_{q\in Q} c^k_q x^k_{nq} \quad (1)$$

$$\textbf{s. t.} \sum_{q\in Q} x^k_{nq} \le 1, \forall n \in N, k \in K \quad (2)$$

$$\sum_{n\in N} x^k_{nq} \le A^k_q, \forall k \in K, \forall q \in Q \quad (3)$$

$$x^{\text{RRH}}_{n_1 q} + x^{\text{RRH}}_{n_2 q} \le 1, \forall q \in Q, \forall (n_1, n_2) \in \beta_q, n_1 \ne n_2 \quad (4)$$

$$x^{\text{BBU}}_{nq} \ge x^{\text{RRH}}_{nq}, \forall n \in N, q \in Q \quad (5)$$

$$\sum_{n\in N} x^{\text{BBU}}_{nq} \le \sum_{n\in N} x^{\text{RRH}}_{nq}, \forall q \in Q \quad (6)$$

$$x^{\text{MEC}}_{nq} \ge x^{\text{RRH}}_{nq}, \forall n \in N, q \in Q \quad (7)$$

$$\sum_{n\in N} x^{\text{MEC}}_{nq} \le \sum_{n\in N} x^{\text{RRH}}_{nq}, \forall q \in Q \quad (8)$$

$$\sum_{n\in N} y_{un} \le 1, \forall u \in U \quad (9)$$

$$\sum_{u\in U} y_{un} \le \sum_{q\in Q} U^{\max}_q x^{RRH}_{nq}, \forall n \in N \quad (10)$$

$$\sum_{n\in N} y_{un} t_{\text{M}} \le t_u \le \sum_{n\in N}\sum_{q\in Q} \delta_{unq} y_{un} x^{\text{RRH}}_{nq}, \forall u \in U \quad (11)$$

$$y_{un} t_{\text{M}} \le \sum_{q\in Q} \delta_{unq} x^{\text{RRH}}_{nq}, \forall u \in U, n \in N \quad (12)$$

$$\sum_{u\in U}\sum_{q\in Q} y_{un} x^{\text{RRH}}_{nq} \delta_{unq} \le \sum_{q\in Q} \delta^{\text{RRH}}_q x^{\text{RRH}}_{nq}, \forall n \in N \quad (13)$$

$$\sum_{u\in U}\sum_{n\in N} y_{un} \ge \lceil \alpha |U| \rceil \quad (14)$$

$$z^{\text{MEC}}_{unq} \le x^{\text{MEC}}_{nq}, \forall u \in U, n \in N, q \in Q \quad (15)$$

$$\sum_{u\in U}\sum_{q\in Q} z^{\text{MEC}}_{unq} \ge \sum_{q\in Q} x^{\text{MEC}}_{nq}, \forall n \in N \quad (16)$$

$$\sum_{n\in N}\sum_{q\in Q} z^{\text{MEC}}_{unq} \le 1, \forall u \in U \quad (17)$$

$$\sum_{u\in U}\sum_{n\in N}\sum_{q\in Q} z^{\text{MEC}}_{unq} \ge \lceil \alpha |U| \rceil \quad (18)$$

$$\sum_{u\in U}\sum_{q\in Q} z^{\text{MEC}}_{unq} t_u \le \sum_{q\in Q} \delta^{\text{MEC}}_q x^{\text{MEC}}_{nq}, \forall n \in N \quad (19)$$

$$x^k_{nq} \in \{0, 1\}, \forall n \in N, \forall k \in K, \forall q \in Q \quad (20)$$

$$y_{un} \in \{0, 1\}, \forall u \in U, n \in N \quad (21)$$

$$z^{\text{MEC}}_{unq} \in \{0, 1\}, \forall u \in U, n \in N, q \in Q \quad (22)$$

$$t_u \ge 0, \forall u \in U \quad (23)$$

The goal of the above formulation is minimizing the total installed cost of such a 5G Superfluid network. The constraints (2) and (3) assure that each RFB module k can be installed on a 5G node in at most one of its type, and the total number of such activated RFB modules is then bounded by the available number all over the network per each type q. Constraint (4) indicates that the same type of RRH RFBs can not be simultaneously installed in two 5G nodes where the minimum separation distance due the radio interference is violated, i.e., 400 meters for Macro RRH RFBs and 50 meters for the Micro one. Constraints (5)-(8) specify the activation of BBU RFBs and MEC RFBs, respectively, as mapping relationship among RFBs modules are all one to one. Constraints (9) and (10) denote that a user can be served by at most one node, and the maximum number of served users by a 5G node is then bounded by its given capacity. Constraint (11) indicates that the downlink traffic assigned to any user should satisfy its minimum required demand and be limited by the provided maximum radio-link capacity of corresponding 5G node. Constraint (12) guarantees that a user gets served by a 5G node if and only if the provided maximum radio-link capacity is bigger than its minimum required traffic to avoid an insufficient downlink traffic being received. Moreover, constraint (13) expresses the capacity constraints of RRH RFBs in terms of radio-link capacity. Constraint (14) indicates that the minimum required coverage of users should be guaranteed. Similarly to RRH RFBs, the capacity constraints of MEC RFBs in terms of traffic capacity are then characterized by constraints (15)-(19): a user gets served at most by one activated MEC RFB over the network, and the total users served by MEC RFBs has to satisfy the minimum required covered users. Moreover, the total downlink traffic provided to connected users on a 5G node is then bounded by the maximum total traffic managed by MEC RFBs installed on this node. Finally, constraints (20)-(23) define feasible domains of decision variables.

The constraints (11), (13) and (19) are non linear, but can be easily linearized by a standard well-known approach. Hence $\forall u \in U, n \in N, q \in Q$, we have:

$$\theta_{unq} \ge 0 \quad (24)$$

$$\theta_{unq} \le y_{un} \quad (25)$$

$$\theta_{unq} \le x^{\text{RRH}}_{nq} \quad (26)$$

$$\theta_{unq} \ge y_{un} + x^{\text{RRH}}_{nq} - 1 \quad (27)$$

$$t_{unq} \le z_{unq}^{\text{MEC}} \delta_u^{\text{MAX}} \tag{28}$$

$$t_{unq} \le t_u \tag{29}$$

$$t_{unq} \ge t_u + (z_{unq}^{\text{MEC}} - 1)\delta_u^{\text{MAX}} \tag{30}$$

$$t_{unq} \ge 0 \tag{31}$$

where $\delta_u^{\text{MAX}} = \max\{\delta_{unq} | \forall n \in N, q \in Q\}, \forall u \in U$.

D. Simplification of the model

The above model is still large and one needs to consider simplifying it in order to make its solution tractable. In an optimal solution of the aforementioned model, the all user downlink traffics will be set to t_{M} as our objective function is to minimize the total construction costs of a Superfluid network. Hence, constraint (19) can be rewritten as:

$$\sum_{u \in U} \sum_{q \in Q} z_{unq}^{\text{MEC}} t_{\text{M}} \le \sum_{q \in Q} \delta_q^{\text{MEC}} x_{nq}^{\text{MEC}}, \forall n \in N \tag{32}$$

and constraint (11) is obviously implied by (12).

Secondly, a given value of $x_{nq}^{\text{MEC}} = 1, \forall n \in N$ implies that:

$$\sum_{u \in U} z_{unq}^{\text{MEC}} \ge 1, \forall n \in N, q \in Q \tag{33}$$

$$\sum_{n \in N} z_{unq}^{\text{MEC}} \le 1, \forall u \in U, q \in Q \tag{34}$$

$$\sum_{u \in U} z_{unq}^{\text{MEC}} t_{\text{M}} \le \delta_q^{\text{MEC}}, \forall n \in N, q \in Q \tag{35}$$

Then the maximum number of served users by an activated MEC RFB of type q is an optimal solution of the following problem:

$$\textbf{max} \sum_{u \in U} \sum_{n \in N} z_{unq}^{\text{MEC}} \tag{36}$$

$$\textbf{s.t.} \text{ Constraints } (34) - (35) \text{ and } (22) \tag{37}$$

where constraint (33) is obviously implied by objective function (36). The above problem is a so-called uniform 0-1 knapsack problem. Especially all weights of items are identical, the above problem hence is easy to solve, its optimal value is then defined by $\lfloor \delta_q^{\text{MEC}} / t_{\text{M}} \rfloor$.

Therefore, the constraints $(15) - (19)$ are then simplified by following constraint:

$$\sum_{n \in N} \sum_{q \in Q} x_{nq}^{\text{MEC}} \lfloor \delta_q^{\text{MEC}} / t_{\text{M}} \rfloor \ge \lceil \alpha |U| \rceil \tag{38}$$

Besides, the managed capacity of a MEC RFB of type q (δ_q^{MEC}) is bigger than the one of an RRH RFB of the same type (δ_q^{RRH}) as presented in Table III. In an optimal solution, the maximum number of served users for a 5G node of type q is smaller than the minimum of $U_q^{\max}$ and $\delta_q^{\text{MEC}}/t_{\text{M}}$, which means the activation of MEC RFBs only depends on its type. Hence, in an one-to-one mapping relationship for RRH RFB, BBU RFB and MEC RFB, the activation of BBU RFBs and MEC RFBs can be represented with the one of RRH RFBs. The aforementioned mathematical model is then rewritten as:

$$\textbf{min} \sum_{n \in N} \sum_{q \in Q} c_q^{\text{RFBC}} x_{nq}^{\text{RRH}} \tag{39}$$

$$\textbf{s.t.} \sum_{q \in Q} x_{nq}^{\text{RRH}} \le 1, \forall n \in N \tag{40}$$

$$\sum_{n \in N} x_{nq}^{\text{RRH}} \le \min_{k \in K} \{A_q^k\}, \forall q \in Q \tag{41}$$

$$\sum_{u \in U} y_{un} \le \sum_{q \in Q} \min \left\{ U_q^{\max}, \lfloor \delta_q^{\text{MEC}} / t_{\text{M}} \rfloor \right\} x_{nq}^{\text{RRH}}, \forall n \in N \tag{42}$$

$$\sum_{n \in N} \sum_{q \in Q} x_{nq}^{\text{RRH}} \lfloor \delta_q^{\text{MEC}} / t_{\text{M}} \rfloor \ge \lceil \alpha |U| \rceil \tag{43}$$

$$x_{nq}^{\text{RRH}} \in \{0, 1\}, \forall n \in N, q \in Q \tag{44}$$

$$\text{Constraints } (4), (9), (12)\text{-}(14) \text{ and } (21) \tag{45}$$

where constraint (41) indicates that the activated RRH RFBs is bounded by the minimum available number among the RFB modules. Constraint (42) denotes that the maximum number of served users on a 5G node is bounded by both RRH RFBs and its served MEC RFBs. Constraint (43) specifies the minimum number of activated RRH RFBs implied by the activation of MEC RFBs.

TABLE III: Input parameters in line with these presented in [8]

Parameters	value	
	Micro	Macro
U_q^{MAX}	42	126
A_q^{RRH}	81	5
A_q^{BBU}	81	5
A_q^{MEC}	81	5
c_q^{RRH}	53951[€]	133951[€]
c_q^{BBU}	440[€]	1307[€]
c_q^{MEC}	440[€]	1307[€]
c_q^{RFBC}	54831[€]	136565[€]
δ_q^{RRH}	10[Gbps]	30[Gbps]
δ_q^{MEC}	30[Gbps]	30[Gbps]

IV. Computational Results

A. 5G test scenarios

We consider a 5G network composed of 9x9 candidate nodes that covers an area where the users are quasi-uniformly located around the center of network as shown in Fig.3. Network parameters such as the maximum radio-link capacity per user per node per RRH RFB and the initial maximum served number of users by each RRH RFB are computed as in [9]. For different test scenarios, the number of users is varied from 25 to 100 with a step of 25, from 100 to 300 with a step of 50, and from 500 to 1000 with a step of 250. In line with these eleven 5G scenarios, we set up the minimum user downlink traffic t_{M} varying from 10 to 50 Mbps with a step of 20, and the minimum required ratio of coverage $\alpha \in$ [0.1, 1.0] with a step of 0.1. Besides, a 8G maximum virtual memory for the whole program where 4G limitation for working memory

TABLE IV: Computational experiments on 330 instances

	M						MA						MAS					
NbUsers	NO	NI	NT	NM	TOA(s)	TIA(s)	NO	NI	NT	NM	TOA(s)	TIA(s)	NO	NI	NT	NM	TOA(s)	TIA(s)
25	30	0	0	0	578.91	-	30	0	0	0	5.15	-	30	0	0	0	0.19	-
50	1	0	29	0	822.81	-	30	0	0	0	8.57	-	30	0	0	0	0.45	-
75	0	0	30	0	-	-	30	0	0	0	19.47	-	30	0	0	0	0.433	-
100	0	0	30	0	-	-	30	0	0	0	38.02	-	30	0	0	0	0.931	-
150	0	0	30	0	-	-	27	0	3	0	144.77	-	30	0	0	0	2.96	-
200	0	0	30	0	-	-	23	0	7	0	318.26	-	30	0	0	0	36.03	-
250	0	0	0	30	-	-	16	1	13	0	325.96	136.85	25	1	4	0	28.89	6.47
300	0	0	0	30	-	-	6	2	22	0	362.84	437.03	22	2	6	0	74.70	8.80
500	0	0	0	30	-	-	1	2	27	0	306.45	779.44	18	5	7	0	80.48	23.03
750	0	0	0	30	-	-	1	0	29	0	737.96	-	16	6	8	0	260.51	62.71
1000	0	0	0	30	-	-	0	0	30	0	-	-	7	7	16	0	347.20	129.83
total	31	0	149	150	586.78	-	194	5	131	0	112.38	513.96	268	21	41	0	43.44	67.82

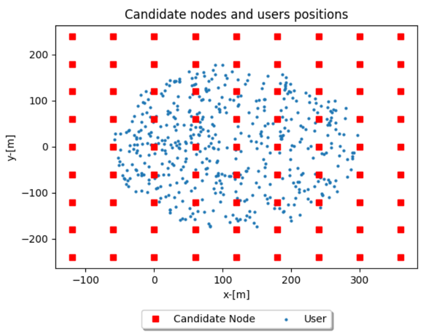

Fig. 3: A 5G network instance with 81 candidate nodes and 500 users

of Cplex solver and a total elapsed time limitation of 900 seconds for experimentation, other input parameters values are summarized in Table III.

B. Numerical results

We evaluate the formulation proposed in [8], the alternative model in this paper, and its simplified version over the above-mentioned scenarios preliminarily in a pure start-of-art solver, i.e. Cplex solver. In Table IV, M denotes the mathematical model involved in [8], MA specifies the proposed model (Section III-C), and MAS is the simplified version, respectively. NO calculates the number of optimal solutions, NI counts the number of infeasible solutions, NT indicates the instances exceeding time limitation, and NM specifies the number of instances can not be solved within 8G virtual memory. Moreover, TOA and TIA indicate the total averaged elapsed time on seconds for an optimal solution and the infeasible one. It is shown in Table IV that the model in [8] attains a big size when the number of served users exceeds 250 such that the program requires more than 8G work memory, which in general it performs poorly compared to our formulation. On the other hand, for those small size instances, the simplified model can be used to solve an instance quasi-immediately, whereas the first model requiring more than 500 seconds. For the infeasible instances, the simplified model always performs better to find a solution. Both the proposed formulation, and more specifically its simplified version, result in a drastic reduction both on computational time and used virtual RAM memory.

V. Conclusions

The compact model showed in SectionIII-C separates all components in a chain of RFBs into its own allocation sub-problem. Consequently, the high combinatory among the sub-problems involved in [8] is then broken down. Moreover, such proposed problem structure can be simplified significantly, where the allocation sub-problems for the other components in a chain of RFBs can be absorbed by the RRH RFB one, in case of the mapping relationships among the families of RFBs are all one to one. The computational time and occupied memory for solving these instances are drastically reduced by the simplified formulations. However, some hard or large-scale instances cannot be solved in 900 seconds by the simplified proposed model via a pure start-of-art solver, the heuristic methods and decomposition strategies (i.e., Benders decomposition) tackling the time costly instances will be in focus of our future work.

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