

# A Performance Comparison of Load Balancing among Radio-over-Fiber Indoor LTE Small Cells

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**Abstract** Radio over Fiber (RoF) is a promising candidate for constructing 4G and 5G mobile optical network. The main feature of the RoF is heterogeneous and centralized processing for the radio resource. In this paper, we compared several algorithms as for the load-balancing scheme. The throughput performance and standard deviation (SD) are evaluated with the different schemes. As a result, it is found that the sorted-greedy achieves the highest throughput with minimum deviation.

**Keywords** RoF, Load-balancing, LTE, Small cell

## 1. Introduction

Currently, 80% of wireless data communication traffic comes from the mobile terminal at indoor environment [1]. To support the growing traffic with heterogeneous wireless air interfaces, Radio over Fiber (RoF) has been proposed for providing a large capacity by virtue of its broad bandwidth and centralized radio frequency (RF) signal processing not only the modulation but also the coordination, resource management among the cells.

To manage the radio resources, RoF working with centralized processing is a combined infrastructure that can transmit signal from the baseband units (BBUs) to the remote antenna units (RAUs) as shown in Fig. 1 [2]. Hence, by offering the resource on demand, the number of BBUs can be reduced by a one to many of wavelength assignment [3]. The BBUs virtualization scheme that minimizes the power consumption has been proposed in [4]. This paper proposed to use the load-balancing scheme working with an optical switch. Hence, the goals of this paper are to minimize the number of BBUs and balance the resources between them.

algorithm. This paper compares the several load-balancing scheme regarding the total amount of throughput performance. It proves that the number of BBUs can be reduced by the resource sharing using an optical switch working with the load-balancing scheme. The rest of this paper is organized as follows. Section 2 presents the system model of this paper. The several load-balancing schemes are described in Section 3. In section 4, the numerical analysis has been analyzed to compare the load-balancing scheme. Section 5 concludes the paper.

## 2. System model

Fig. 1 shows the proposed configuration. At the BBU equips the network interface (I/F) to connect with the optical device. Each BBU holds the single RF channel, and then each RF signal is modulated onto a single wavelength ( $\lambda$ ). From the Fig. 1, the optical switch can reconfigure the fiber-optic connections between the BBUs and RAUs. Then, RF signals are detected at the RAU through the I/F. The centralized control is connected with an optical switch to get the usage information of BBU and offered load, which the load-balancing algorithm can perform in this controller.

We assume  $M$  as the number of BBUs, with equal resources  $R$ . There are  $N$  RAUs in the system, which each RAU is connected to one fixed BBU. If  $M$  is equal to  $N$ , this means the optical switch is not required. The processing resource at BBU- $j$  ( $1, \dots, M$ ) that is used by RAU- $i$  ( $1, \dots, N$ ) according to their actual network load, can be calculated as

$$R_{i,j} = \sum_{p=1}^{P_i} R_{i,p} \leq R, \quad (1)$$

where  $P_i$  and  $R_{i,p}$  are the number of mobile stations in RAU of  $i$ -th and the required processing resource for

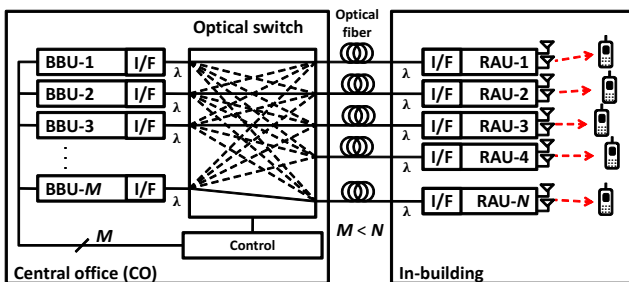


Fig. 1 Proposed RoF network with optical switch

Due to the consuming of the resource in each BBU, the resources may result in imbalance among the BBUs, which depends on the load-balancing

user's offered load of  $p$ -th in RAU  $i$ -th, respectively. And, the  $P = \sum_i P_i$ , where  $P$  is the number of mobile stations in the system.

### 3. Load balancing scheme

Four load-balancing algorithms are proposed, which consist of round robin, sorted-round robin, greedy and sorted-greedy.

#### A. Round-robin and Sorted-round robin scheme

The RAUs are treated as a list; in each repeating process, RAU- $i$  is assigned to BBU- $(i \% M) + 1$ . In the sorted-round robin, the list of RAUs is reordered in non-increasing order, after that each RAU is then attached into the BBU in the same way as in the round robin scheme.

#### B. Greedy and Sorted-greedy scheme

The greedy scheme is a heuristic method for the global optimization problem. Here, RAU- $i$  is assigned to the BBU that has the lowest resource consuming. Similarly, the sorted-greedy scheme reordered the list of RAUs in non-increasing order before employs the greedy scheme.

The used parameters are shown in Table 1.

**Table 1** Summarize the parameters

Parameters	Value
Modulation	64QAM
Number of the antennas	2x2 (MIMO)
Number of the wavelength	1
Number of the RF channel	1
Number of the users in the system ( $P$ )	120, 180
Number of the users in each room ( $P_i$ )	10, 15
Number of the BBUs ( $M$ )	1-12
Number of the RAUs ( $N$ )	12
Bandwidth in each BBU ( $R$ )	20 MHz

### 4. Numerical analysis

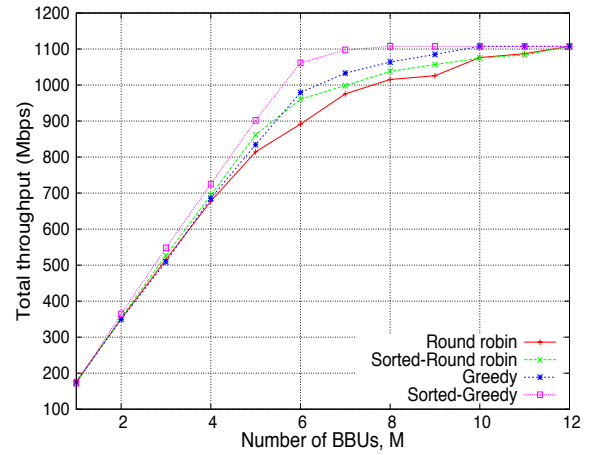
This work assumed that the BBUs equip with the LTE interface. The BBUs and the RAUs are located in the CO and in-building, respectively. The resource elements (RE) in a subframe with 20MHz channel bandwidth can be calculated by 12 subcarriers x 7 OFDMA symbols x 100 resource blocks x 2 slots. As a result, the value of RE per subframe is 16800 REs. Then, the 64QAM modulation scheme was used in the simulation, which each symbol can carry 6 bits. Hence, the data rate of each antenna is 100.8Mbps. By using the 2x2 MIMO, the peak data rate in each BBU goes up to 201.6Mbps.

The building scenario is the 2-floor office building with six rooms on each floor. Each room is attached with one RAU ( $N=12$ ). Due to the offering capacity on demand and responding to traffic requests, each user can be classified into four groups as shown in Table 2.

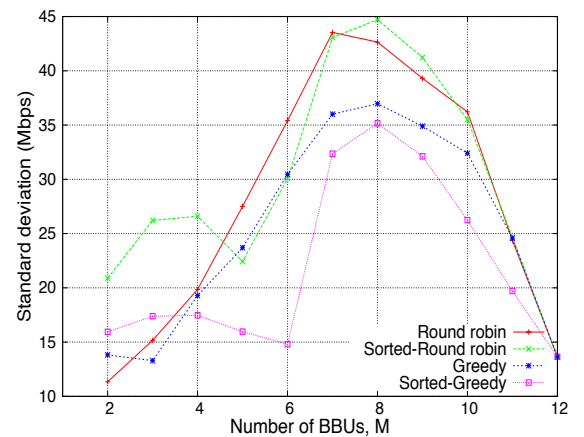
**Table 2** User groups

Groups	Offered load ( $R_{i,p}$ )	% of users in building
1	5 Mbps	50
2	10 Mbps	30
3	15 Mbps	10
4	20 Mbps	10

Fig. 2 shows the total throughput when the number of BBUs ( $M$ ) is changed. In this calculation, each RAU accommodates ten mobile stations, which the mobile stations are simultaneously receiving the data from the CO. If the sorted-greedy is used, it is found that eight BBUs are enough to accommodate all of offered load from the mobile stations. In the case of using sorted-round robin, twelve BBUs must also be used in order to achieve the maximum throughput; this means resources are wasted.



**Fig. 2** Throughput with the number of BBUs ( $M$ ) ( $P=120$ )



**Fig. 3** SD with the number of BBUs ( $M$ ) ( $P=120$ )

Fig. 3 shows the SD of the total throughput among BBUs. In the case of sorted-greedy, the SD is lowest compared with all other because it offers a good load

balance between BBUs. The SD increases until the throughput becomes saturated since the system's throughput is still not yet sufficient. On the contrary, when the number of BBUs is high, the SD performance becomes degraded due to the excess resources.

Fig. 4 and Fig. 5 show the total amount of throughput and SD when the number of mobile stations in each room is fifteen. From the results, there is no different between the round robin and the greedy algorithm because each RAU holds the huge network traffic and that almost full of the resources in each BBU. Due to this incident, the RAU and BBU communicate with each other as one by one scenario. This means the variety among the resource-balancing scheme becomes low. In the case of SD, when the number of BBUs is increasing, the SD becomes higher and saturates together.

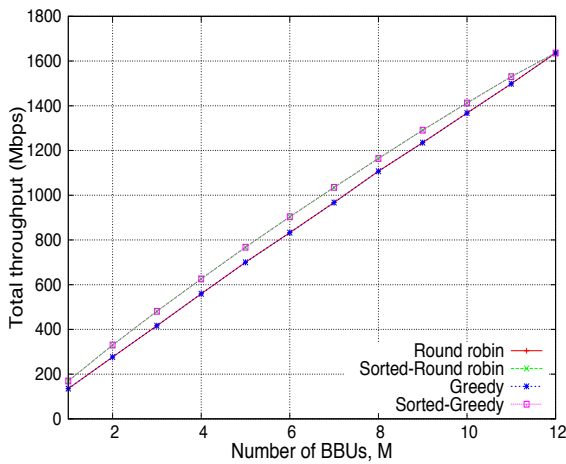


Fig. 4 Throughput with the number of BBUs ( $M$ ) ( $P=180$ )

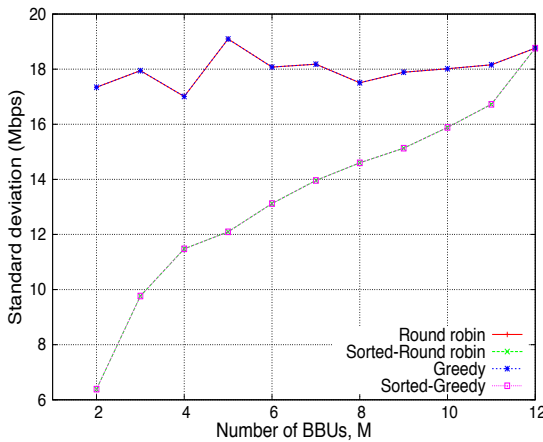


Fig. 5 SD with the number of BBUs ( $M$ ) ( $P=180$ )

The computational complexity of load-balancing scheme is shown in Table 2.

Table 2 Computational complexity

Algorithm	Computational complexity
Round robin	$O(1)$
Sorted-round robin	$O(N \log N)$
Greedy	$O(N)$
Sorted-greedy	$O(N \log N)$

## 5. Conclusions

In this paper, an optical switch working with the RoF network has been proposed to make the flexible connection between the RAUs and BBUs. Due to the user's offered resources demand. We evaluate the performance regarding the QoS. The several load-balancing algorithms that are available for the RoF mobile optical network have been compared. As a result, the sorted-greedy algorithm has good performance in terms of total throughput and SD.

## References

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