IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received November 22, 2017, accepted March 11, 2018, date of publication April 9, 2018, date of current version April 25, 2018.

Digital Object Identifier 10.1109/ACCESS.2018.2818283

Automated Network Load Balancing and Capacity Enhancing Mechanism in Future Network

YI-WEI MA[1], JIANN-LIANG CHEN[2], AND CHIA-JU LIN[2]
[1]China Institute of FTZ Supply Chain, Shanghai Maritime University, Shanghai 201306, China
[2]Department of Electrical Engineering, National Taiwan University of Science and Technology, Taipei City 10607, Taiwan

Corresponding author: Yi-Wei Ma (yiweimaa@gmail.com)

This work was supported by the Ministry of Science and Technology, Taiwan, under Contract MOST 105-2221-E-011-078-MY3 and Contract 105-2221-E-011-076-MY3.

ABSTRACT The available 5G network is going to have various industrial applications. Mobile communication operators will be able more effectively to utilize their spectral assets, provide higher-speed data communication services, and increase network capacity. Traditional network parameters are manually set or adjusted by the network management system, so substantial room exists for improvement in operational speed. Self-organizing networks (SON) provide an automated means of simplifying operational tasks and improving operational efficiency. In future 5G networks, especially, in congested urban areas, difficulties of network management and load balancing will arise. The proposed novel SON management mechanism influences the overall network behavior by arranging the SON function parameters and adjusting the configuration of devices, user-equipment, and small cells. Simulation results indicate that implementing the proposed mechanism increases the throughput by an average of 4% and a maximum of 4.5%.

INDEX TERMS Self-organizing network (SON), 5th generation mobile networks (5G), long term evolution (LTE), 3rd generation partnership project (3GPP).

I. INTRODUCTION

Many network associated parameters in wireless networks are manually configured. Such manual configuration is exhausting and time-consuming, leading to resulting in long delays in updating values, high error rates and suboptimal network performance. Owing to constantly changing network operating conditions and topologies, efficient methods of dealing with these parameters must be managed and planned to ensure the stability and the reliability of networks; nevertheless, the related operational costs are enormous. In current networks, configuration methods depend on the massive collection of data from the network, including statistics and measurements, and considerably depend on human intervention even with existing semi-automated management information systems.

Driven by the sometimes inappropriate reactions to users of network systems, the Self-Organizing Network (SON) concept was defined in the 3GPP (3rd Generation Partnership Project) network management specifications to reduce the amount of human intervention in the installation in small cells. SON provides network intelligence, automation and flexible features for the automatic configuration and optimization of the radio related parameters and the ever-changing network conditions, simultaneously reducing costs and improving network performance.

The features of SON change with the evolution of an LTE network over time and follow the expected maturity of commercial networks. One of the major operational tasks in wireless network environment is the design of a network based on the coverage and capacity of small cells. Coverage and Capacity Optimization (CCO) is a key function of a SON in 3GPP specifications, which complements manual operating methods by adjusting power-related parameters, such as Tx power. As soon as the cells are deployed, the CCO functions are used in the operation, administration and maintenance, continuously receiving the cell load conditions and determining the actions that should be performed.

In future 5G networks, small cells will be densely deployed in urban areas. Cell coverage will be improved, handover efficiency will be enhanced, and migration latency will be reduced relative to those of the LTE network. As the number of mobile users has rapidly grown, the demand for capacity has greatly increased. In crowded urban areas, network loading may not be uniformly distributed, such as when the population concentrates close to offices with relatively sparsely populated residential areas. Therefore, this work

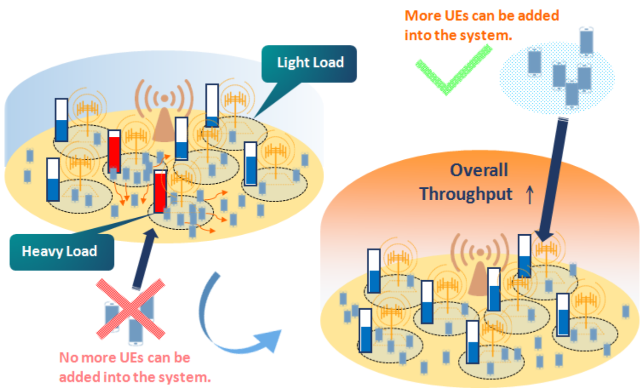

FIGURE 1. The load balancing scenario.

focuses on maximizing the throughput of the overall network; optimizing the use of base stations (BSs); minimizing the response time, and preventing avoiding the overload of any single base station.

In the current network, small cells may be heavily loaded, and new small cells may not be added to the system, as shown in Fig.1. If the load can be balanced across the network, and the overall throughput and capacity in the network can be improved, then more user equipment (UE) can be added to the network, meeting future demand. Data offloading refers to the traffic load from one base station to another. Data offloading reduces data amount in base station and frees up bandwidth for other users or applications [1].

II. BACKGROUND KNOWLEDGE

A. SMALL CELL, MACRO CELL AND eNB

Operators can increase the capacity of their networks by widely deploying small cells or eNodeB (eNB). The smallest example of a small cell is the Home eNB (HeNB), which is a base station with a small coverage area that is suitable for use in a home. HeNB provides users with good coverage and high data rates, and shares the traffic near macro cells. Small cells are fundamental devices for 3G data offloading, and they will be essential for the management of 5G network in the future [2], [3].

B. SELF-ORGANIZING NETWORK SUB-FUNCTIONS

Long Term Evolution (LTE) specifications support the operations of SONs. Small cells that are added to a network will be self-configured, while the parameters of all operating small cells are regularly optimized in response to observed network conditions and performance. Self-healing mechanisms can be applied to temporarily solve a detected problem in the network as the managing system develops a longer-term solution.

1) SELF-CONFIGURATION

The Operations, Administration and Maintenance (OAM) will configure an eNB's Physical Cell Identity, transmission frequency and power, accelerating the speed of cell planning in the network. To reduce the number of manual configuration tasks, Automatic Neighbor Relation (ANR) is applied to the network. ANR configures the list of neighbor eNBs of a newly deployed eNB, and updates the configuration list during operation. When the OAM system adopts centralized-SON assignment, it will a global view and control of the PCIs. When the distributed-SON solution is utilized, the OAM system assigns a list of possible PCIs to the newly deployed small cell, but the adoption of the Physical Cell Identity (PCI) is controlled by the small cell alone. Restated the SON function operates in the OAM when the centralized-SON solution is adopted, but operates in a small cell when the distributed solution is adopted. The newly deployed small cell will request a report from the UEs over the air interface or from other small cells over the X2 interface.

2) SELF-OPTIMIZATION

Most self-optimization functions are described in Release 9 of 3GPP. Mobility load balancing (MLB) is utilized when small cells are congested and load must be transferred to other small cells with available resources. The radio resource status reports are separated into uplink and downlink reports. The small cells must estimate the extent to which the cell border must to be changed, and must design develop a mechanism to avoid the ping-pong effect.

3) SELF-HEALING

The OAM is able to receive the faults of the cellular network periodically. Numerous problems can thus be solved, and in many cases, the hardware can back up its own data. Solving problems in the radio access network is very difficult, because every base station has its own coverage area, making a healing mechanism more difficult for operators to design. Any loss of service within a base station will cause users to experience a lack of availability or significantly degraded service in terms of availability and performance. A possible consequence is loss of revenue for the operator and increased churn. Cell outage compensation refers to the maintenance of the best service for users while repairs are being performed. Return from cell outage compensation refers to the while obviously needed easy return to pre-fault status, reversing any compensation actions that may have been carried out. To enable related use cases to be acted upon, many elements must be included in the network to detect and manage faults that may arise [4].

C. SON OPERATIONAL METHODS

A SON server has default network parameters, such as RF parameters including physical cell identities, antenna tilt, antenna height, azimuth angle and type, the transmission power of the small cell or the macro cell, the maximum configured capacity and the initial neighbor configuration. The SON server is also pre-loaded with transport parameters such as bandwidth, ULAN partition and IP addresses. The ranges of IP addresses and serving gateway addresses that correspond to node information are also loaded into the

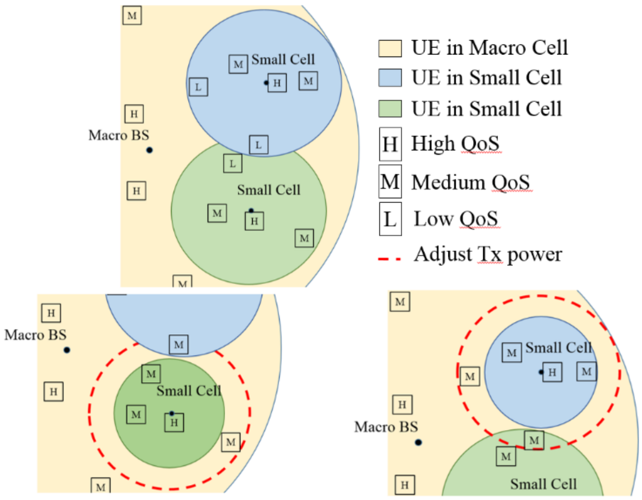

FIGURE 2. The simplified concept of CCO.

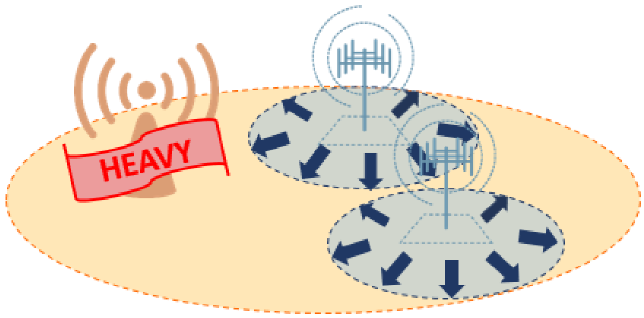

FIGURE 3. When macro cell is heavily loaded.

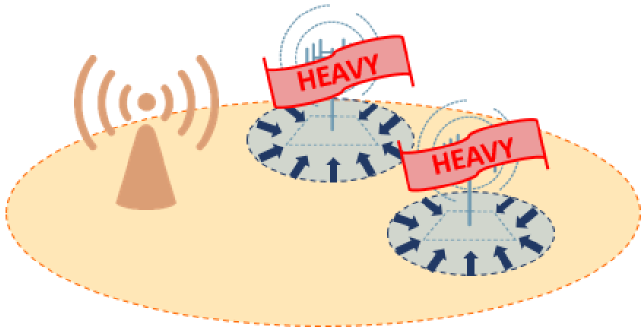

FIGURE 4. When small cell is heavily loaded.

SON server [5], [6]. As soon as the base station is installed in the network, powered on, and connected to a transport link, the SON operational methods take over all of the configuration or optimization processes of the base station [7]–[16].

1) COVERAGE AND CAPACITY OPTIMIZATION

Increasing the capacity and improving the coverage of the network during SON operation are equally important. Both coverage and capacity of the CCO SON are important. A SON function is executed to meet the operator's objectives concerning coverage and capacity, and the tradeoff between them [17]. Figure 2 presents a simplification of the concept of CCO. As a small cell coverage reaches its maximum load, the CCO function detects the condition and automatically turns down the power, causing UEs on the edge of the cell with the weakest connections to be offloaded to the macro cell. Therefore, various real-time algorithms in different nodes can simultaneously balance the uneven load across the network, increasing the overall throughput [18]–[20].

D. OPERATIONS, ADMINISTRATION AND MANAGEMENT (OAM)

Based on the needs of network operators, network management tasks are typically divided into three categories of operation, administration and maintenance. Operation involves mainly the analysis, prediction and planning of daily networks; administration involves the collection of information that is required for network planning; maintenance concerns mostly with problems that arise during operational activities and daily network testing [21]–[29].

E. RELATED WORKS

Reference [30] introduce the problem of offloading in WiFi networks, and proposed heterogeneous data offloading algorithm to solve relate issue. Reference [31] proposed a framework to deal with data offloading in mobile network. Reference [32] given a complete introduction about data offloading. Reference [33] proposed a method which combined with opportunistic networks for data offloading.

III. AUTOMATED NETWORK LOAD BALANCING AND CAPACITY ENHANCING ARCHITECTURE

A. SYSTEM OVERVIEW

In the proposed system architecture, the operational module comprises the monitor module, the coverage allocation module and the Automated Load Balancing and Capacity Enhancement (ALBCE) mechanism module, enabling the control and management of the overall network. In this investigation, only the power of a small cell is configured, to reduce the complexity of the configuration methods and to stabilize the coverage of the macro cell. This configuration method prevents the UEs that were originally under the macro cell from moving in and out of the macro cell too frequently as the coverage of the macro is configured, as presented in Figs. 3 and 4. If the macro cell is heavily loaded, then the system increases the coverage of a small cell, offloading UEs into the small cell's coverage area. However, if a small cell is heavily loaded, then the system reduces the coverage of the small cell, offloading UEs into the coverage area of the macro cell. In this investigation, the mobility of users is ignored not considered. At the moment of the measurement, every UE is assumed to be static.

Figure 5 shows the architecture of the proposed system, elucidating the main modules.

- ➢ Coverage Allocation: The system predicts the throughput of the overall network in the next period based on

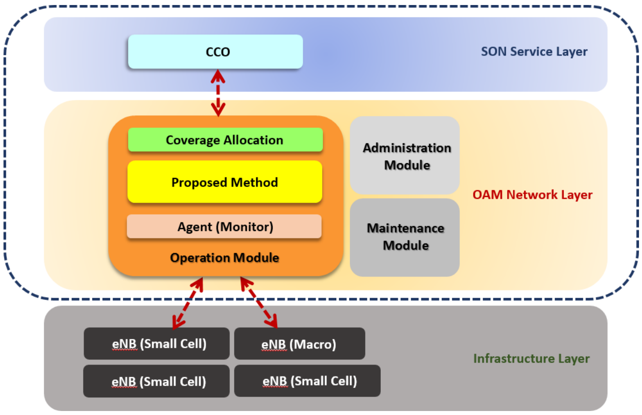

FIGURE 5. The proposed system architecture.

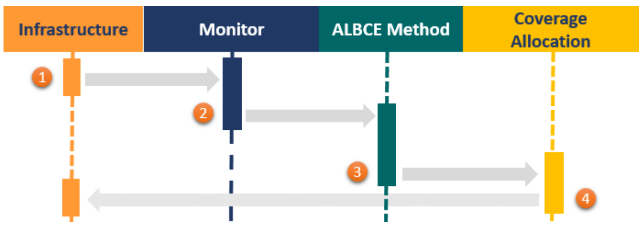

FIGURE 6. The overall operation time sequence.

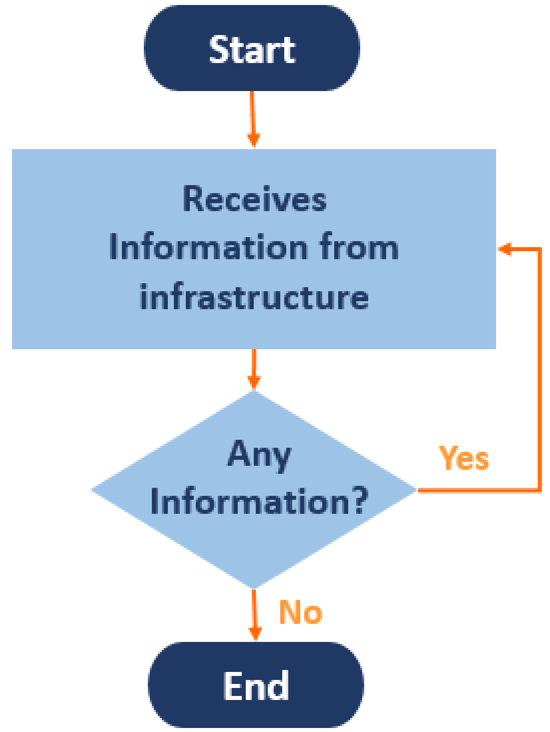

FIGURE 7. The monitor procedure.

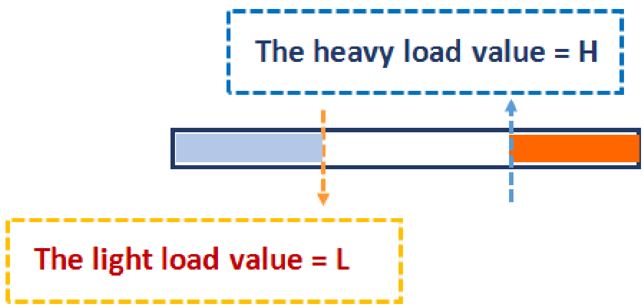

FIGURE 8. The definition of heavy load and light load value.

historical throughput information, and then configures the coverage of small cells to achieve load balancing and improve throughput.

➢ ALBCE Mechanism: The proposed mechanism determines whether a small cell or macro cell is heavily loaded, and then calculates the resources that are provided or needed by the small cell. It is also responsible for finding a means of offloading at the lowest cost.

➢ Monitor: The monitoring module is a part of the agent, which supports communication between the SON server and the infrastructure. The module periodically and automatically receives the downlink throughput of small cells and the macro cell. These parameters will be used in further calculations.

Figure 6 presents the overall sequence of operations. The proposed infrastructure sends information to the monitoring module of the OAM. The monitoring module periodically receives the downlink throughput and the user number the macro cell and small cells, and then sends the received information for use in the ALBCE method. The proposed ALBCE method determines whether a small cell or macro cell is heavily loaded, and then calculates the resource that is provided or requested by a small cell. Finally, the ALBCE method identifies the way to offload small cells at the lowest cost, and sets the power a small cell.

B. PROPOSED MECHANISMS

1) MONITOR

In order to implement the CCO function, the SON architecture must support automatic data gathering based on network monitoring. The proposed ALBCE mechanism requires the monitoring of a large area of the network to identify CCO-related issues and changes in the values of parameters. This work develops a power configuration mechanism for small cells to offload UEs to other small cells or a macro cell. The monitoring module periodically receives the downlink throughput and the user number of the macro cell and small cells and inputs this information to the ALBCE mechanism. Figure 7 displays a flow chart of the monitoring process.

The heavy load H and the light load L are defined herein; if the loading of a small cell or macro cell exceeds H, then it is regarded as heavily loaded; if the loading of a small cell or macro cell is lower than L, then it is categorized as lightly loaded. This definition prevents the excessively frequent adjustment of the power of a small cell, which results in bad service quality. Figure 8 displays the definition of heavy load and light load value.

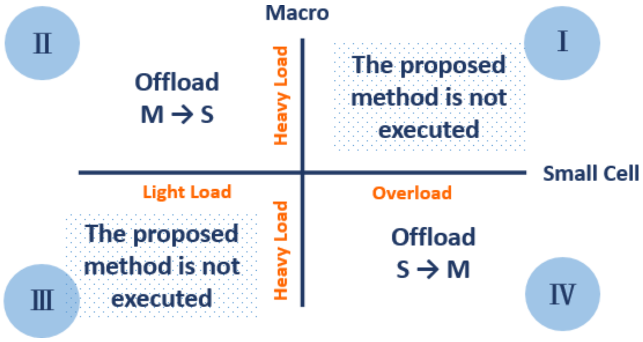

FIGURE 9. Offloading decision of ALBCE.

2) ALBCE MECHANISM

In this proposal, UEs and small cells adopt the standard measurement rules and follow a series of fundamental rules that are based on 3GPP. The general goal of using this novel SON mechanism that is based on small cell deployments is to minimize operational effort and expense.

a: THROUGHPUT PREDICTION

Every period, any change in throughput is recorded and the predicted throughput value is calculated in this study. The predicted throughput is given by function (1). b_i represents the throughput in period i; b_{i-1} is the throughput in period i-1, and n is the number of previous periods that are used for predicting the throughput. V_1 is the change in throughput from period1 to period2; V_2 is the change in throughput from period2 to period3; V_i is the change in throughput from period i to period i+1, and so on. In the function, the mean of the previous variations of throughput is used to predict the throughput in the next period. The best number n of previous periods that yields the most accurate prediction is determined herein. If the number of previous periods is less than n, then the system counts the number of prediction periods and divides the sum of variations by the number of previous periods. For example, if n equals 4 and the system is to predict the value of b_4, then the system adds V_1 to V_3 and divides the result by three.

$$b_i = b_{i-1} + [V_1 + V_2 + V_3 + \cdots + V_n]/n \tag{1}$$

When the total network throughput of every cell in the next period has been predicted, the system checks the loading conditions of all cells. The loading conditions of small cells and the macro cell are divided into four ranges, represented by the four quadrants in Fig. 9. If both the small cell and the macro cell are heavily loaded or lightly loaded, then the proposed ALBCE mechanism is not executed. If a small cell is heavily loaded but the macro cell is lightly loaded, then the system offloads UEs from the small cells to the macro cell. If a small cell is lightly loaded and the macro cell is heavily loaded, then the system offloads UEs from the macro cell to that small cell.

Figure 10 shows the flow chart of the offload decision process. First, the system checks whether both the small cells and the macro cell are heavily loaded, and if so, it takes no action; otherwise, the system checks whether both the macro cell and the small cells are lightly loaded. If all are lightly loaded, the system takes no action. Then, the system determines whether the macro cell is heavily loaded and the small cell is lightly loaded; if so, the system offloads the macro cell to the small cell; if not, the system offloads the small cell to the macro cell. Then, the ALBCE mechanism proceeds to the next step of identifying which small cells to configure.

The offload decision process is shown as following pseudo code.

The field has $Macro_1, Macro_2, \ldots, Macro_m$(m Macro Cell Devices) and $Small_1, Small_2, \ldots, Small_n$, (n Small Cell Devices).

Initialize

System checks the small cells and the macro cell who are heavily loaded.

Main

if (Small cells & Macro Cell == heavily loaded){
System takes no action
}
if (Small cells & Macro Cell == lightly loaded){
System takes no action
}
if (Macro Cell == heavily loaded & Small cells == lightly loaded){
System offloads the macro cell to the small cell
}
if (Macro Cell == lightly loaded & Small cells == heavily loaded){
System offloads the small cell to the macro cell
}

(i) OFFLOAD MACRO CELL TO SMALL CELL

If the macro cell is heavily loaded and small cells are lightly loaded, then the system offloads UEs from the macro cell to the small cells. The ALBCE mechanism calculates the resources that are provided by the small cells and the resources that are requested by the macro cell. The small cells are sorted by load. The system begins the offloading process by increasing the coverage of the small cells. Figure 11 shows the procedure of offloading from macro cell to small cell.

Figure 12 shows a flow chart for comparing the radio resource with Requested Resource (RR), which is a register that represents the requested amount of the radio resource, and Provided Resource (PR) that represents the provided amount of that resource. In this case, where the offload from the macro cell to small cells, small cells provides the resource, and the macro cell requests the resource. Initially, the system examines the loadings of the cells one by one; if small cell i is heavily loaded, then its loading, Si information will be

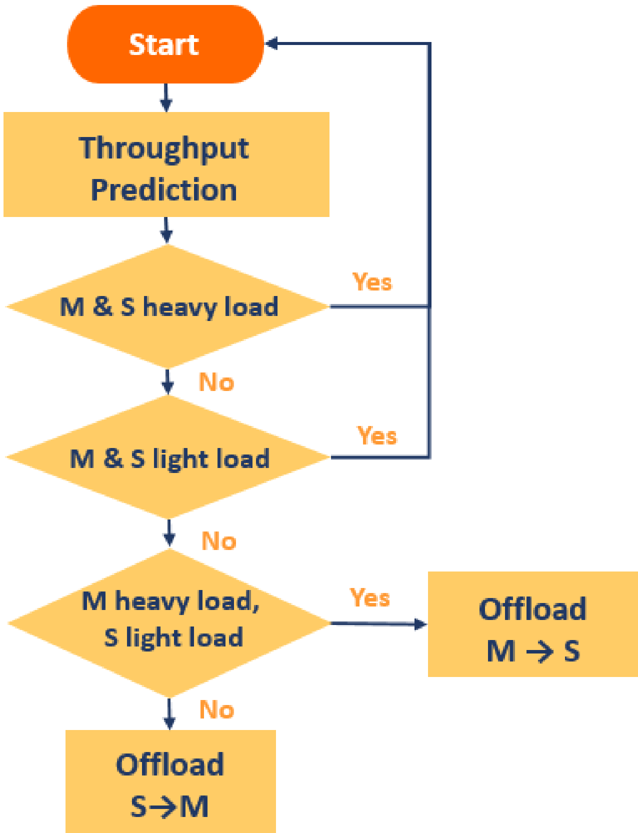

FIGURE 10. The offload decision process.

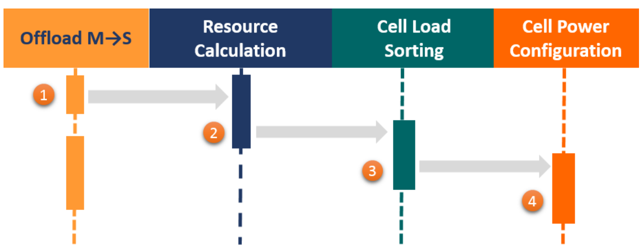

FIGURE 11. The procedure of offloading from macro to small cell.

stored in PR. If a heavily loaded small cell is identified, then its loading will be included in PR. The resource that is requested by the macro cell is stored in RR. If RR > PR, meaning that the requested amount of a resource exceeds the provided amount of a resource, then the system sets RR to PR, indicating that only 'RR' of the resource for small cells is offloaded to the macro cell. If RR is less than or equal to PR, then the system keeps adding the requested resource to RR until it exceeds PR. Thereafter, the system calculates the cost of migration.

(ii) OFFLOAD SMALL CELL TO MACRO CELL

If the small cells are heavily loaded and the macro cell is lightly loaded, then the system offloads UEs from the small cells to the macro cell. The ALBCE mechanism calculates the resource that is provided by the macro cell and the resource

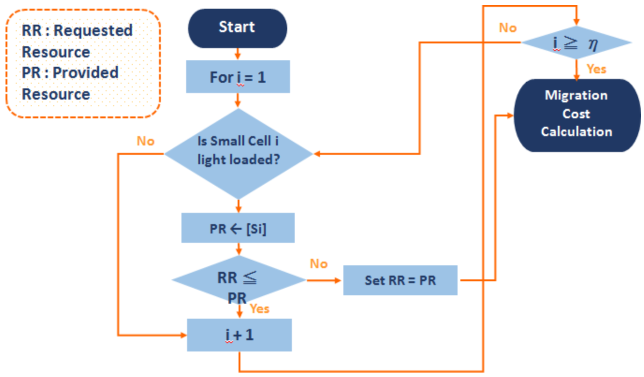

FIGURE 12. The flow chart of resource comparison (offload from MacroCell to small cell).

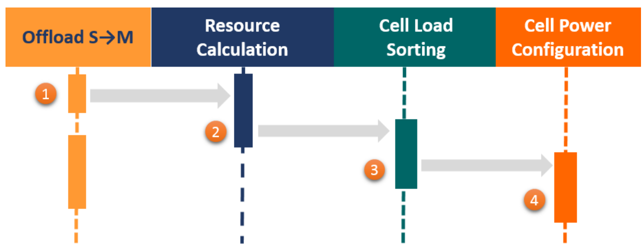

FIGURE 13. The procedure of offloading from small to macro cell.

that is requested by the small cells. Then, the small cells are sorted by loading. The system begins the offloading process by increasing the coverage of small cells. Figure 13 shows the procedure of offloading from small cell to macro cell.

Figure 14 shows the flow chart for the offload decision. RR represents the requested amount of the requested resource, and PR represents the provided amount of that resource. When from a small cell to the macro cell, the macro cell provides the resource, and the small cell requests the resource. Initially, the system examines the loadings of the small cells one by one; if small cell i is heavily loaded, then the loading value, Si, will be input to RR. If another heavily loaded small cell is detected, then its loading value will be stored in RR. The resource that is requested by the macro cell is stored in PR. If RR > PR, meaning that the requested resource exceeds the provided resource, then the system sets RR to PR, indicating that only 'RR' of the resource less than small cells is offloaded to the macro cell. If RR is less than or equal to PR, then the system keeps adding the requested resource to RR until it exceeds PR. Thereafter, the system proceeds to calculating the cost of migration.

b: MIGRATION COST FUNCTION

Loading, throughput, and latency costs are considered in the migration cost function that is used by the system in selecting cells to offload. The proposed mechanism offloads UEs to a cell in a manner that minimizes the cost; finds the optimal means of offloading in each period, and adjusts the Tx power of each Cell according to the policy that is set by the ALBCE mechanism. A few assumptions are made herein:

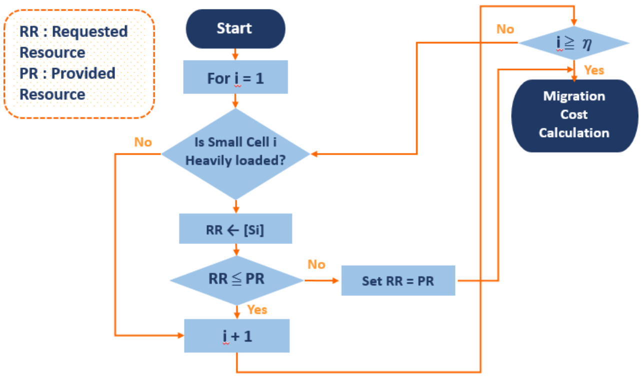

FIGURE 14. The flow chart of resource comparison (offload from small cell to macro cell).

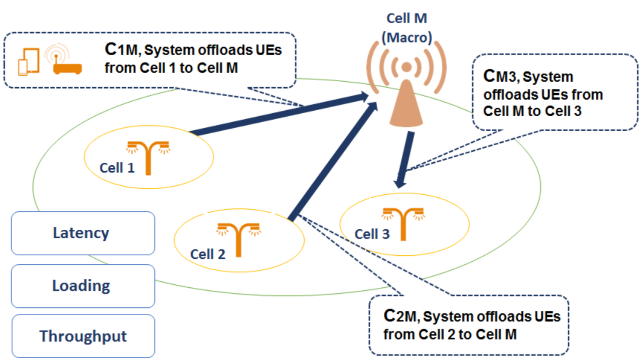

FIGURE 15. The scenario of migration cost function.

first, UEs are uniformly distributed among all small cells, and no small cell overlaps another, so interference between small cells can be neglected. Second, the throughputs of all UEs are equal, and assumed to be β. Finally, the network includes n UEs. Figure 15 shows the scenario of migration cost.

In this study, the loading cost is Lij; the throughput cost is Tij, and the latency cost is dij, which is given by formula (2). minCij is the minimum cost to achieve the maximum performance. The migration cost model incorporates three weighting values for the loading, the throughput, and the latency, as follows.

$$MinC_{ij} = W_1 L_{ij} + W_2 d_{ij} + W_3 T_{ij} \tag{2}$$

Under the following constraints.

$$L_{ij}, d_{ij}, T_{ij} > 0 \tag{3}$$

C_{ij} is the migration cost of moving UEs from Cell i to Cell j; L_{ij} is the increase in the number of users under the coverage of Cell j; d_{ij} is the amount of time after a mobile device successfully hands over to its target cell; T_{ij} is the limit on the downlink throughput from Cell i to Cell j. To prevent latency, loading, or throughput costs from dominating the migration cost function, these three cost values are normalized. L_{ij} is defined as $\frac{Loading}{Loading_{max}}$, d_{ij} is defined as $\frac{HO}{HO_{max}}$, and T_{ij} is defined as $\frac{Thr}{Thr_{max}}$.

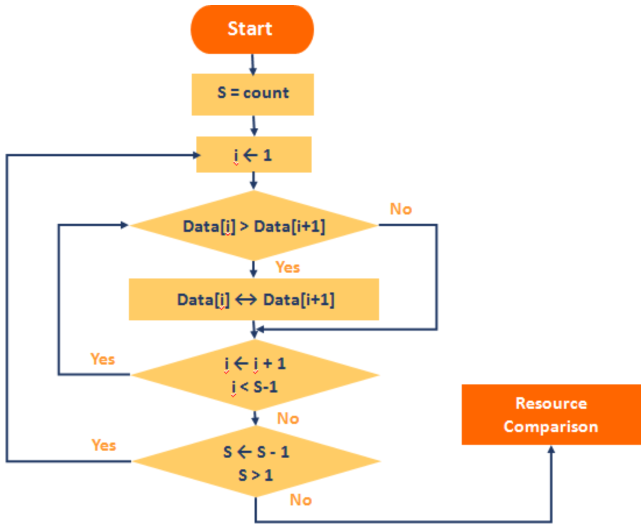

FIGURE 16. The flow chart of migration cost sorting.

As defined by function (3), W is the weighting of every considered cost in the cost function. The sum of W_1, W_2 and W_3 is unity, as in function (4). If any of the three cost values become less or more important, the weighting values can be adjusted accordingly.

$$W_1 + W_2 + W_3 = 1 \tag{4}$$

After the cost values have been calculated, the system ranks them in ascending order using Bubble sort, which is a simple and stable sorting algorithm. S is the number of small cells in the experimental environment. The sorting begins by comparing each pair of elements from the beginning of an array, Data[i] and Data[i+1], and determining whether the value of Data[i] exceeds that of Data[i+1]. If not, then they are swapped. The system then adds 1 to i to examine the next cost value. After one loop has been completed, the value of S is reduced by one. If at least one swap has been performed, then the system repeats the comparison step. The sorting process can be imagined as the floating of a large bubble to a surface, following each step, where it remains. The sorting ends when the no bubble no longer moves. The point of this process is to arrange the cost values from small to large for further calculations. Figure 16 shows the flow chart of migration cost sorting.

To determine the number of small cells whose coverage should be adjusted, the system compares the first element in the array with the resource that is provided by a small cell or the macro cell. If the cost is lower than the provided resource, then it is stored in register B. The system then proceeds to compare the next cost value, array Data[i] , with the value of the in all instances provided resource. If the next cost value is lower than the provided resource, then it is also added to register B. As soon as the cost value in register B exceeds the provided resource, the comparison terminates, and the system prepares for the set the Tx power of the small cells. Figure 17 shows the flow chart of resource comparison.

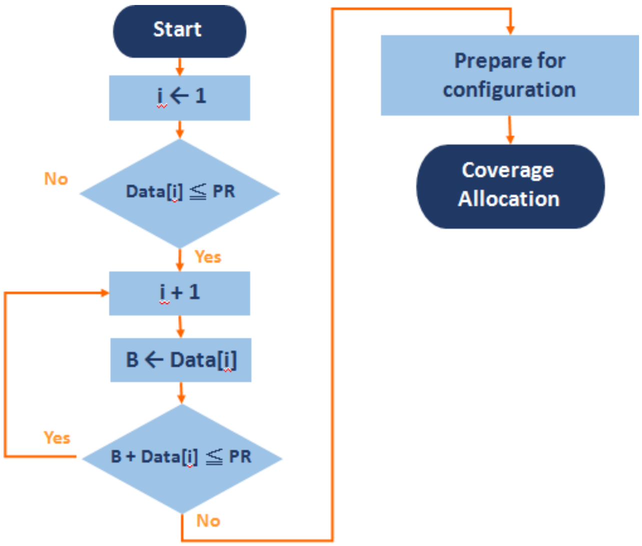

FIGURE 17. The flow chart of resource comparison.

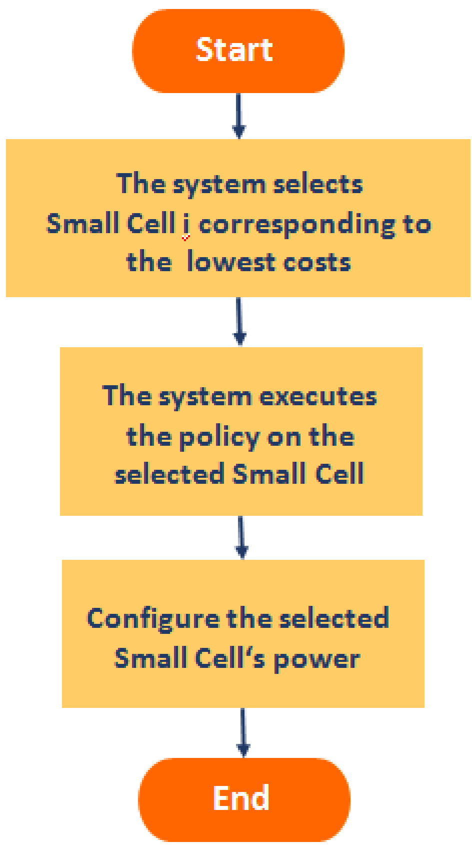

FIGURE 18. The flow chart of coverage allocation.

3) COVERAGE ALLOCATION

The system sets the Tx power of a small cell to determine its coverage. The flow chart in Fig.18 below captures the configuration process. First, the system selects small cell i with the lowest cost and applies a policy to it. Finally, the system sets the power of selected small cell.

TABLE 1. The received parameters by CCO.

CCO Parameters	
Configuration Parameters	Antenna Tilt
	Antenna Azimuth
	Antenna Model
Cell	Power
	Throughput
	Call Success Rate
	Call Drop Rate
Handover Matrix	Handover Relations between cells
	Handover failures
Interference Matrix through Call Trace measurements from UE	RSCP from Serving cell
	RSCP from all neighbors
Site Configuration Parameters	Site Location and Height

TABLE 2. The applied Tx power value.

	Licensed Cell	Unlicensed Cell
Total Small Cell Tx Power	**24 dBm**(total per carrier)	**18 dBm** across aggregated carriers. Optional: **24 dBm**
Total UE Tx Power Total	Total UE Tx Power: **23 dBm** across aggregated cells. Max total UE Tx power per cell in licensed spectrum: **23 dBm** Max total UE Tx power across aggregated cells in unlicensed spectrum: **18 dBm**	

Tx power is set as follows.

$$P_t = (D_r)xP_{max} + P_i \tag{5}$$

According to function (5), P_t is the power provided by the small cell at time t; P_{max} is the maximum power provided by a small cell; P_i is the power at the initial state of small cell i, and D_r is the configuration ratio that is determined using the ALBCE method.

IV. SYSTEM DESIGN AND PERFORMANCE ANALYSIS

A. EXPERIMENTAL ENVIRONMENT

The area of the simulation network environment is 1200(m) × 1000(m). Large red dot with three antennas indicates the macro cell; the large red dot without antennas indicates a small cell, and the small blue point indicates a UE. The network environment includes 84 UEs, seven macro cells, and 42 small cells, and the UE throughput is 19.93Mb/s. Table 1 presents the parameters that can be configured by the CCO service. The power the small cell is adjusted by the OAM.

Table 2 presents the maximum power of a small cell. For licensed small cells, the Tx power is 24dBm per carrier. For unlicensed small cells, the Tx power is 18dBm per carrier. In the simulation environment, the maximum small cell power is set to a total of 24dBm per carrier.

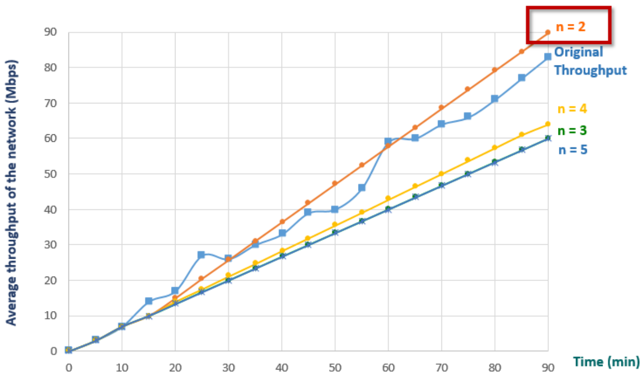

FIGURE 19. The simulation results of different prediction periods.

B. SYSTEM IMPLEMENTATION

The proposed mechanism is executed on small cells with SON functions. The distributions of small cells and UEs are uniform, and extreme conditions, such as the crowding of UEs at the edge of a cell or in the areas with stronger signal, are not considered.

C. PERFORMANCE ANALYSIS

Numerous assumptions will be elucidated and an overview of the simulation environment is provided. Then, the simulated scenario and the applied SON functions will be explained thoroughly. Finally, the steps of the proposed mechanism will be described in detail.

1) THE SELECTION OF THE PREDICTION PERIOD

As described in the preceding section, changes in throughput are recorded and a predicted throughput value is calculated in each period. The predicted throughput is defined as follows.

$$b_i = b_{i-1} + [V_1 + V_2 + V_3 + \cdots + V_n]/n \qquad (6)$$

where b_i is the throughput in period i; b_{i-1} is the throughput in period i-1, and n is the number of periods that are used to predict throughput. V_1 is the change in throughput from period1 to period2; V_2 is the change in throughput from period2 to period3; V_i is the change in throughput from period i to period i+1, and so on. The function uses the mean of previous variations in throughput to predict the throughput in the next period. The best number of previous periods n that maximizes the accuracy of the prediction is found. If the number of previous periods is less than n, then the system divides the sum of the variations among those periods by the number of periods. For example, if n equals four and the system is to predict the value of b_4, then the system adds V_1 to V_3 and divides the result by three. In the experiment, the values two, three, four and five are used in the proposed function so the throughput in the next period is predicted using the throughputs in two, three, four and five preceding periods. The simulation reveals that the predicted value is closest to the actual throughput when n equals two. Figure 19 shows the simulation results of different prediction periods.

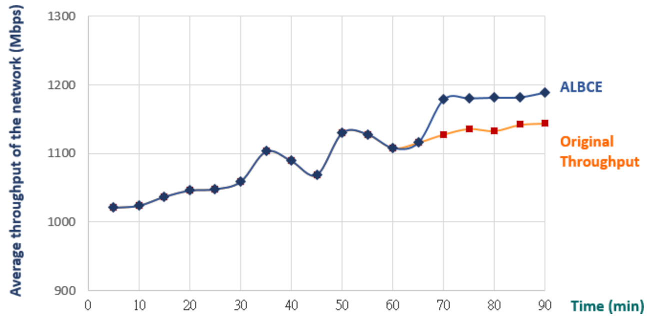

FIGURE 20. The overall throughput of the network.

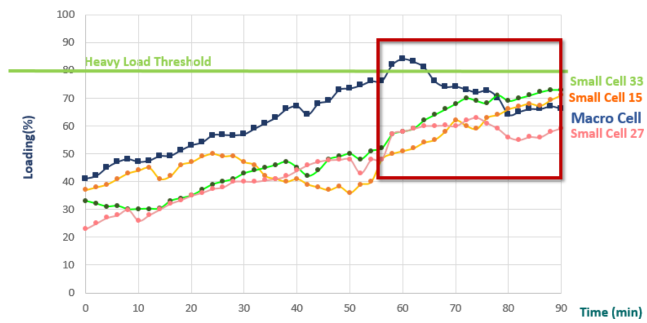

FIGURE 21. Offloading from macro cell to small cell.

2) COMPARISON WITH THE ORIGINAL NETWORK

The throughput performance of the original network without any existing mechanisms is compared with that after the application of the ALBCE mechanism. The result demonstrates that the proposed mechanism improves the overall throughput by an average of 1.0402% and a maximum of 1.045%. Figure 20 shows the overall throughput of the network.

3) LOAD BALANCING CONDITION

Figure 21 shows the loading condition of a macro cell that is offloaded to small cells. The y axis represents the load on the macro and a small cell as a percentage. The x-axis represents time in seconds. The heavy load threshold is set to be 80% of the cell's maximum load. When the macro cell's loading exceeds 80% of a cell's load, the ALBCE mechanism automatically detects this fact and begins to find lightly loaded small cells. After the system calculates the offloading costs and compares the resource that is provided by small cells with that required by the macro cell, it configures the small cells' power with the lowest costs. When a macro cell becomes heavily loaded, the system offloads some of the macro's load to three small cells. The loading of the three small cells begins to increase, and finally the macro cell ceases to be heavily loaded, as shown in the rectangular area of Fig. 21.

Figure 22 shows the loading condition of a small cell that is offloaded to the macro cell. The y axis represents the load on the macro cell and the small cells as a percentage. The x-axis represents time in seconds. The heavy load threshold is set to 80% of a cell's maximum load. When a small cell's

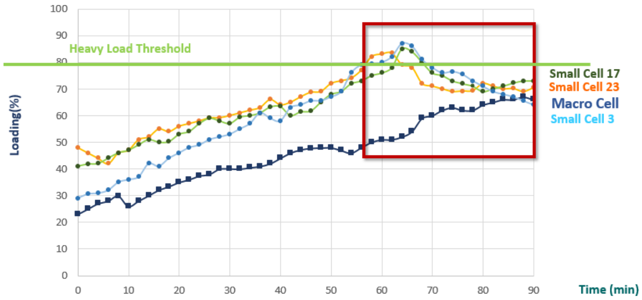

FIGURE 22. Offloading from small cell to macro cell.

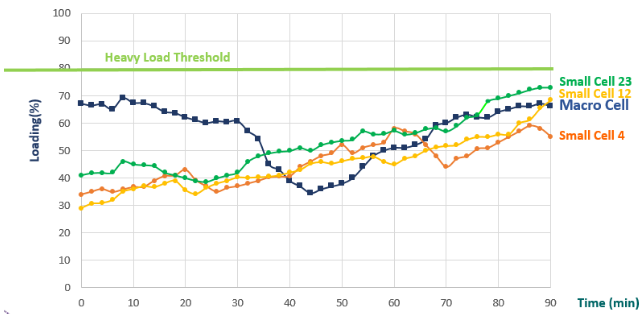

FIGURE 23. When small cell and macro cell are both light loaded.

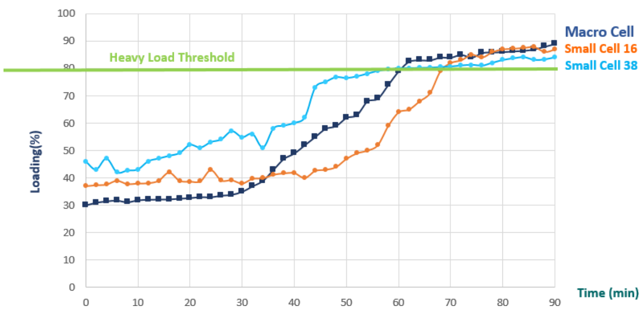

FIGURE 24. When small cell and macro cell are both heavily loaded.

loading exceeds 80%, the ALBCE mechanism automatically detects this fact and begins to identify lightly loaded small cells. After the system calculates the costs of offloading and compares the resource that is provided by the macro cell with that required by the small cells, it configures the small cells' power with the lowest costs. When four small cells are heavily loaded, the system offloads some of their load to the macro cell. The loading of the four small cells falls to under 80% N of the maximum, so the small cells are no longer heavily loaded as shown in the rectangular area of Fig. 22.

Figure 23 shows the light loading of both small cells and the macro cell. Throughout the simulation period, neither the loading of the small cell nor that of the macro cell ever exceeds the heavy load threshold, so the ALBCE mechanism is not executed.

Figure 24 shows the heavy loading of both the small cells and the macro cell. In the simulation period, the loading of the small cells and that of the macro cell both exceed the heavy load threshold so the ALBCE mechanism is not executed.

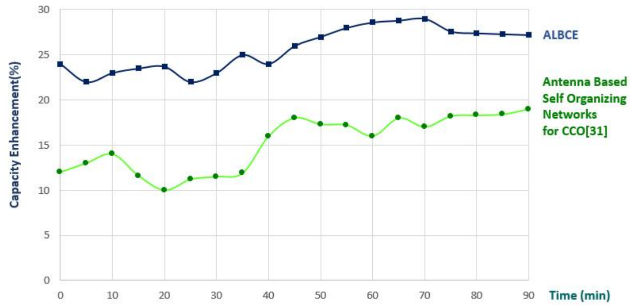

FIGURE 25. Comparison with existing CCO mechanism.

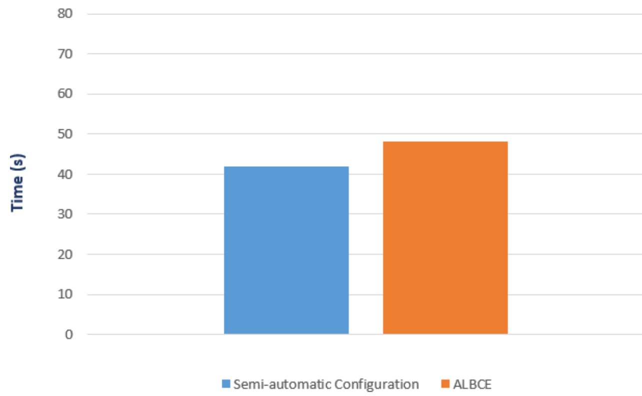

FIGURE 26. The comparison of calculation time.

4) COMPARISON WITH EXISTING MECHANISMS

In another study [34], antenna tilt was used as a CCO parameter. The use of antenna tilt in CCO has been extensively considered in the field of radio engineering. The lower curve in Fig. 25 shows the increase in the capacity of the existing antenna by the SON CCO mechanism. The upper curve shows the increase in the capacity that is achieved using the ALBCE mechanism. The capacity enhancement that is achieved using ALBCE mechanism, approximately 0.936%, is clearly greater than that achieved by the existing CCO mechanism.

5) TRADEOFF

Despite the superiority of ALBCE, a tradeoff exists between loading and the calculation time of the algorithm. Figure 26 shows the relevant flow chart. The ALBCE mechanism requires more calculation time because it involves more calculations. The calculation time is 1.428% greater than that of the currently used semi-automatic SON configuration mechanism.

Figure. 27 shows the numbers of cells, the ALBCE mechanism and the original network. The horizontal axis represents the number of simulation periods. The lower curve in the figure plots the original network, where the network without applying any optimization mechanism. One small cell is seen to be configured in the first period; two small cells are adjusted in the second period; two small cells are adjusted in the third period; four small cells are adjusted in the fourth

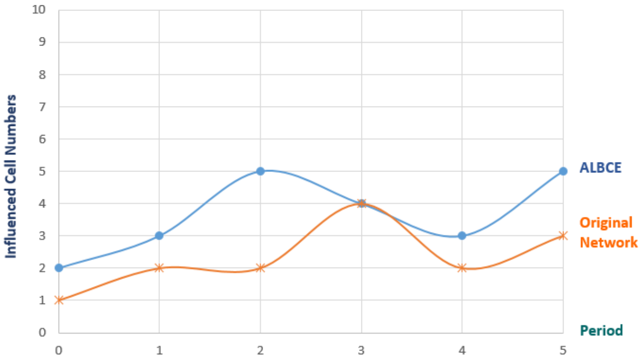

FIGURE 27. The comparison of the influenced small cell numbers.

period; two small cells are adjusted in the fifth period, and three small cells are adjusted in the sixth period. The upper curve plots the number of cells whose power are adjusted by the OAM, the ALBCE mechanism; two small cells are adjusted in the first period; three small cells are adjusted in the second period; five small cells are adjusted in the third period; four small cells are adjusted in the fourth period; three small cells are adjusted in the fifth period, and five small cells are adjusted in the sixth period. The number of the influenced small cells in the network by applying the proposed ALBCE mechanism is obviously larger than the number of the influenced small cells in the network without applying any optimization mechanisms, because adjusting more small cells involves more users, increasing the cost for operators.

6) SUMMARY

This work proposes a throughput prediction method and involves an experiment to find the best prediction period. The experiment results demonstrate that predicted throughput value is closest to the actual throughput when n equals 2. The throughput performance of an original network without any mechanism for compare with that after the ALBCE mechanism has been applied. The proposed mechanism improves the overall throughput. With respect to load balancing, simulation results demonstrate that, if the small cell and macro cell are both heavily loaded, the ALBCE mechanism is not executed. If the small cell and the macro cell are both lightly loaded, or, if the small cell is heavily loaded and the macro cell is lightly loaded, then the ALBCE mechanism is not executed. If the macro cell is heavily loaded and the small cell is lightly loaded, then the ALBCE mechanism is executed, and load balancing is achieved. The throughput achieved using the existing antenna-based mechanism is lower than that achieved using the proposed ALBCE mechanism. Although the ALBCE mechanism improves the capacity of the network, the time required to simulate exceeds that to simulate the original CCO mechanism so room for improvement exists.

V. CONCLUSION

In this work, a novel SON solution for optimizing the total throughput of small cells and a macro cell is proposed and simulated. The results shows that the increase in overall throughput indicates that the proposed mechanism improves the performance of the overall network. The ALBCE algorithm periodically updates the downlink throughput and number of users calculates the status of the radio resource of both small and macro cells, and makes an offload decision. Further improvements in actual urban areas with complex user mobility modes. The benefits of the proposed ALBCE mechanism are not limited to load balancing and capacity enhancement as they also include cost saving and increased revenue generation.

REFERENCES

[1] L. Xu *et al.*, "Self-optimised joint traffic offloading in heterogeneous cellular networks," in *Proc. Int. Symp. Commun. Inf. Technol.*, Sep. 2016, pp. 263–267.

[2] I. Z. Kovács, D. Laselva, P.-H. Michaelsen, Y. Wang, R. Djapic, and K. Spaey, "Performance of SON for RSRP-based LTE/WLAN access network selection," in *Proc. Int. Symp. Wireless Commun. Syst.*, Aug. 2014, pp. 360–364.

[3] I. G. Ben Yahia, C. Destré, and A. Quenot, "Scenarios for eNodeB and SON functions programmability," in *Proc. IEEE Wireless Commun. Netw. Conf. Workshops (WCNCW)*, Apr. 2014, pp. 208–212.

[4] S. Hahn and T. Kürner, "Managing and altering mobile radio networks by using SON function performance models," in *Proc. Int. Symp. Wireless Commun. Syst.*, Aug. 2014, pp. 214–218.

[5] C. Schmelz, S. Hahn, A. Eisenblatter, S. Lohmüller, C. Frenzel, and T. Kürner, "SON management demonstrator," in *Proc. IEEE Netw. Oper. Manage. Symp. (NOMS)*, May 2014, pp. 1–2.

[6] J. Bae, Y. S. Choi, J. S. Kim, and M. Y. Chung, "Architecture and performance evaluation of MmWave based 5G mobile communication system," in *Proc. Int. Conf. Inf. Commun. Technol. Converg. (ICTC)*, Oct. 2014, pp. 847–851.

[7] J. Moysen and L. Giupponi, "Self coordination among SON functions in LTE heterogeneous networks," in *Proc. IEEE Veh. Technol. Conf.*, May 2015, pp. 1–6.

[8] U. Dampage and C. B. Wavegedara, "A low-latency and energy efficient forward handover scheme for LTE-femtocell networks," in *Proc. IEEE 8th Int. Conf. Ind. Inf. Syst.*, Dec. 2013, pp. 53–58.

[9] D. Matsuo, M. Morita, T. Nobukiyo, and Y. Matsunaga, "Adaptive coverage control using cell-specific beamforming based on throughput prediction," in *Proc. IEEE 26th Annu. Int. Symp. Pers., Indoor, Mobile Radio Commun. (PIMRC)*, 2015, pp. 1360–1364.

[10] H. Wang, X. Zhou, and M. C. Reed, "Coverage and throughput analysis with a non-uniform small cell deployment," *IEEE Trans. Wireless Commun.*, vol. 13, no. 4, pp. 2047–2059, Apr. 2014.

[11] N. T. K. Jørgensen, T. Isotalo, K. Pedersen, and P. Mogensen, "Joint macro and femto field performance and interference measurements," in *Proc. IEEE Veh. Technol. Conf. (VTC Fall)*, Sep. 2012, pp. 1–5.

[12] T. Aoyama, K. Ishibashi, M. Bandai, M. Kuroda, and T. Watanabe, "Handover latency analysis on mobile ethernet," in *Proc. IEEE Wireless Commun. Netw. Conf.*, 2005, pp. 1389–1394.

[13] C. Liu and L. Wang, "Optimal cell load and throughput in green small cell networks with generalized cell association," *IEEE J. Sel. Areas Commun.*, vol. 34, no. 5, pp. 1058–1072, May 2016.

[14] C. Li, J. Zhang, and K. B. Letaief, "Throughput and energy efficiency analysis of small cell networks with multi-antenna base stations," *IEEE Trans. Wireless Commun.*, vol. 13, no. 5, pp. 2505–2517, May 2014.

[15] C. Frenzel, S. Lohmüller, and L. C. Schmelz, "Dynamic, context-specific SON management driven by operator objectives," in *Proc. IEEE Netw. Oper. Manage. Symp. (NOMS)*, May 2014, pp. 1–8.

[16] P. Vlacheas, E. Thomatos, K. Tsagkaris, and P. Demestichas, "Operator-governed SON coordination in downlink LTE networks," in *Proc. IEEE Future Netw. Mobile Summit*, Jul. 2012, pp. 1–9.

[17] G.-K. Chang, C. Liu, and L. Zhang, "Architecture and applications of a versatile small-cell, multi-service cloud radio access network using radio-over-fiber technologies," in *Proc. IEEE Commun. Workshops (ICC)*, Jun. 2013, pp. 879–883.

[18] G. Bartoli *et al.*, "Beamforming for small cell deployment in LTE-advanced and beyond," *IEEE Wireless Commun.*, vol. 21, no. 2, pp. 50–56, Apr. 2014.
[19] J. Huang, H. Zhang, W. Xu, and H. Zhang, "Grouping based inter-cell interference coordination in LTE-a dense small-cell networks," in *Proc. IEEE Microw., Antenna, Propag. EMC Technol. Wireless Commun. (MAPE)*, Oct. 2013, pp. 78–83.
[20] T. Yamamoto and S. Konishi, "Impact of small cell deployments on mobility performance in LTE-advanced systems," in *Proc. IEEE Pers., Indoor Mobile Radio Commun. (PIMRC Workshops)*, Sep. 2013, pp. 189–193.
[21] A. Gupta and R. K. Jha, "A survey of 5G network: Architecture and emerging technologies," *IEEE Access*, vol. 3, pp. 1206–1232, 2015.
[22] S. Berger, A. Fehske, P. Zanier, I. Viering, and G. Fettweis, "Comparing online and offline SON solutions for concurrent capacity and coverage optimization," in *Proc. IEEE 80th Veh. Technol. Conf. (VTC-Fall)*, Sep. 2014, pp. 1–6.
[23] M. Iwamura, "NGMN view on 5G architecture," in *Proc. IEEE 81st Veh. Technol. Conf. (VTC Spring)*, May 2015, pp. 1–5.
[24] G. Seçinti and B. Canberk, "A spatial optimization based adaptive coverage model for green self-organizing networks," in *Proc. IEEE 11th Consum. Commun. Netw. Conf. (CCNC)*, Jan. 2014, pp. 495–500.
[25] I. Luketić, D. Šimunić, and T. Blajić, "Optimization of coverage and capacity of self-organizing network in LTE," in *Proc. 34th Int. Conv.*, May 2011, pp. 612–617.
[26] R. Romeikat, H. Sanneck, and T. Bandh, "Efficient, dynamic coordination of request batches in C-SON systems," in *Proc. IEEE Veh. Technol. Conf. (VTC Spring)*, Jun. 2013, pp. 11–16.
[27] J. Zhang, C. Sun, Y. Yi, and H. Zhuang, "A hybrid framework for capacity and coverage optimization in self-organizing LTE networks," in *Proc. IEEE 24th Annu. Int. Symp. Pers., Indoor, Mobile Radio Commun. (PIMRC)*, Sep. 2013, pp. 2919–2923.
[28] C. Tran and Z. Dziong, "Traffic trend estimation for profit oriented capacity adaptation in service overlay networks," *IEEE Trans. Netw. Service Manage.*, vol. 8, no. 4, pp. 285–296, Dec. 2011.
[29] S. Berger, A. Fehske, P. Zanier, I. Viering, and G. Fettweis, "Online antenna tilt-based capacity and coverage optimization," *IEEE Wireless Commun. Lett.*, vol. 3, no. 4, pp. 437–440, Aug. 2014.
[30] G. Gao, M. Xiao, J. Wu, K. Han, L. Huang, and Z. Zhao, "Opportunistic mobile data offloading with deadline constraints," *IEEE Trans. Parallel Distrib. Syst.*, vol. 28, no. 12, pp. 3584–3599, Dec. 2017.
[31] H. Shah-Mansouri, V. W. S. Wong, and J. Huang, "An incentive framework for mobile data offloading market under price competition," *IEEE Trans. Mobile Comput.*, vol. 16, no. 11, pp. 2983–2999, Nov. 2017.
[32] F. Rebecchi, M. D. de Amorim, V. Conan, A. Passarella, R. Bruno, and M. Conti, "Data offloading techniques in cellular networks: A survey," *IEEE Commun. Surveys Tuts.*, vol. 17, no. 2, pp. 580–603, 2nd Quart., 2015.
[33] C. Wang, Y. Li, and D. Jin, "Mobility-assisted opportunistic computation offloading," *IEEE Commun. Lett.*, vol. 18, no. 10, pp. 1779–1782, Oct. 2014.
[34] Y. Khan, B. Sayrac, and E. Moulines, "Surrogate based centralized SON: Application to interference mitigation in LTE-A HetNets," in *Proc. IEEE Veh. Technol. Conf. (VTC Spring)*, Jun. 2013, pp. 1–5.

YI-WEI MA received the M.S. degree in computer science and information engineering from National Dong Hwa University, Hualien, Taiwan, in 2008, and the Ph.D. degree from the Department of Engineering Science, National Cheng Kung University, Tainan, Taiwan, in 2011. He is currently a Lecturer with Shanghai Maritime University. His research interests include Internet of Things, cloud computing, multimedia p2p streaming, digital home network, embedded system, and ubiquitous computing.

JIANN-LIANG CHEN was born in Taiwan in 1963. He received the Ph.D. degree in electrical engineering from National Taiwan University, Taipei, Taiwan, in 1989. Since 2008, he has been with the Department of Electrical Engineering, National Taiwan University of Science and Technology, where he is currently a Professor. His current research interests are directed at cellular mobility management and personal communication systems.

CHIA-JU LIN received the M.S. degree in electrical engineering from the National Taiwan University of Science and Technology, Taipei, Taiwan. Her research interest include Software-define networking, network virtualization, and future network.