RSCMF: A Mapping Framework for Resource Scalability Collaboration in Radio Access Networks with SDR and Virtualization

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Abstract

A unified mapping framework called resource scalability collaboration (RSCMF) is proposed, which jointly optimizes heterogeneous radio access networks and provides customized service applications. To support resource scalability collaboration, infrastructure is virtualized into network functions (VNF) by virtualization technology and software defined radio. To support the loose coupling of applications and infrastructure, based on VNF, logical mapping and physical mapping are applied. The logical mapping implements customized function for the application by quantitative analysis decision tree and virtual function orchestration. The physical mapping optimizes the global performance via scalable resource collaboration. We present the architecture, design challenges, and key technologies of RSCMF through our initial research efforts and illustrate how to use resource scalable collaboration to maximize the resource utilization. We also provide examples of logical and physical mapping based on traffic load and energy consumption and quality of service, when topology changes dynamically.

Keywords: Mapping, Scalable collaboration, Radio access networks, Software defined radio, Virtualization

1 Introduction

With the proliferation of mobile demands and increasingly multifarious services and applications, network topology becomes more and more intensified, network system and devices become more and more diversified (multi-standard, multi-air-interface) than traditional forms [19-20]. However, efficient business support is difficult to accomplish because different business types under current network protocol are with the same air-interface, thus resulting in difficulties in rapid deployment of new business types. Meanwhile, the diversified network nodes and forms not only bring heavy load in the network, but also make the user experience differ. In [21], Mobility First wiki has revolutionized a complete new plan to verify the future network framework. In [22], Allied Business Intelligence has pointed that the number of Wi-Fi amounted to 4.2 million in 2013, amounted to 4.85 million in 2014, while the number will amount to 10.5 million in 2018. Obviously, great expenses will be paid for the revolutionary reform of next generation radio access network. Thus, it is not efficient to have one platform support all the one network services. For those problems of stiffness for radio access networks, a flexible, intellectual and open framework for radio access network is desperately needed [1-5, 13, 21-23].

Meanwhile, another aspect that the future radio access networks should be evolutionary, collaborative and innovative in contrast with traditional forms, has been studied in [1]. Collaborative communication can effectively manage heterogeneous network resources to improves coverage, interference suppression, and load balance. For example, Song etc. have presented a policy framework for resource management in a loosely coupled cellular and WLAN integrated network, where load balancing policies are designed to efficiently utilize the pooled resources of the network [2]. In [3], Yu and Krishnamurthy have proposed a joint session admission control scheme for multimedia traffic that maximizes overall network revenue with quality of service (QoS) constraints over both the tight coupling WLAN and the CDMA cellular networks.

Traditional collaborative communication does not call the radio resources of the other heterogeneous networks to be used in the same platform, which implements resource collaboration outside the two systems. Accordingly, software defined radio (SDR) is proposed to serve as a relatively common hardware platform [4, 13]. It realizes the function of communication via software and realizes the programming control of work frequency, transceiver power, system bandwidth, modulation mode, source coding [13]. Meanwhile, SDR can rapidly change the channel access mode or modulation mode, and adapt to

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different norms to construe multi-model and multi-function bases of high flexibility, thus to interact between different communication systems.

The precondition of SDR's rapid change is to abstract a virtualized access of software or hardware by virtualization technology (VT) based on infrastructure to allow upper software to be directly operated on virtualized environment [5, 23]. By the division of time division multiplexing or spatial division multiplexing, and simulator, and network virtualization, one resource is abstracted into many and many resources are abstracted into one, making resources free of physical constraints.

However, current collaborative communication strategies only apply to limited range in radio resource [1-3], and they can not support the ubiquitous open access. For the integration of heterogeneous networks, users want to get the tailored service with various network functional modules. However, achieving this goal faces following challenges. First, the resources cannot exchange, or share radio resource between different partners, or migrate to another, in radio heterogeneous network access system. Second, logics of the application and resources of infrastructure can not be quantitively matched, making it difficult to realize the flexible cooperation among resources. Finally, radio access will become smart at low expenses.

To address above challenges, we introduce a resource mapping framework for scalable collaboration in radio access networks with SDR and VT, as shown in Figure 1. RSCMF is to guarantee infrastructure and application being open and independent. When the logics of application change, it does not necessarily change the lower level network. Meanwhile, when the infrastructures of radio access network changes, it does not necessarily mean that the logics of the application will change. First, we abstract the infrastructure of radio access network with SDR and VT, screen lower layer information of various heterogeneous resources and express it as VNF. Then, we will construct quantitative analysis decision tree (QADT) to tailor VNFs for the application. Meanwhile, in order to use the lowest cost, to realize the "tailored" functions of the application, we put forward a virtual network function orchestration (VFO) strategy. Finally, physical mapping is used to configure physical nodes to maximize the usage of infrastructure. Our contributions are as follows: (1) We proposed a mapping framework for resource scalability collaboration in radio access networks with SDR and virtualization. This Framework can jointly optimize heterogeneous radio access networks and provide customized service application. (2) We have done the research on scalable collaboration of radio communication resource by resource mapping of LTE's two different working modes: TDD and FDD. This framework could increase the utilization rate of the total resources to above 95%. (3) We have done the research on dynamic change of topology, RSCMF framework tries to make system energy efficient on the premise of guaranteeing quality of experience (QoE). When the network load is medium, RSCMF prefers QoE. When the network load is high, RSCMF prefers internet throughput.

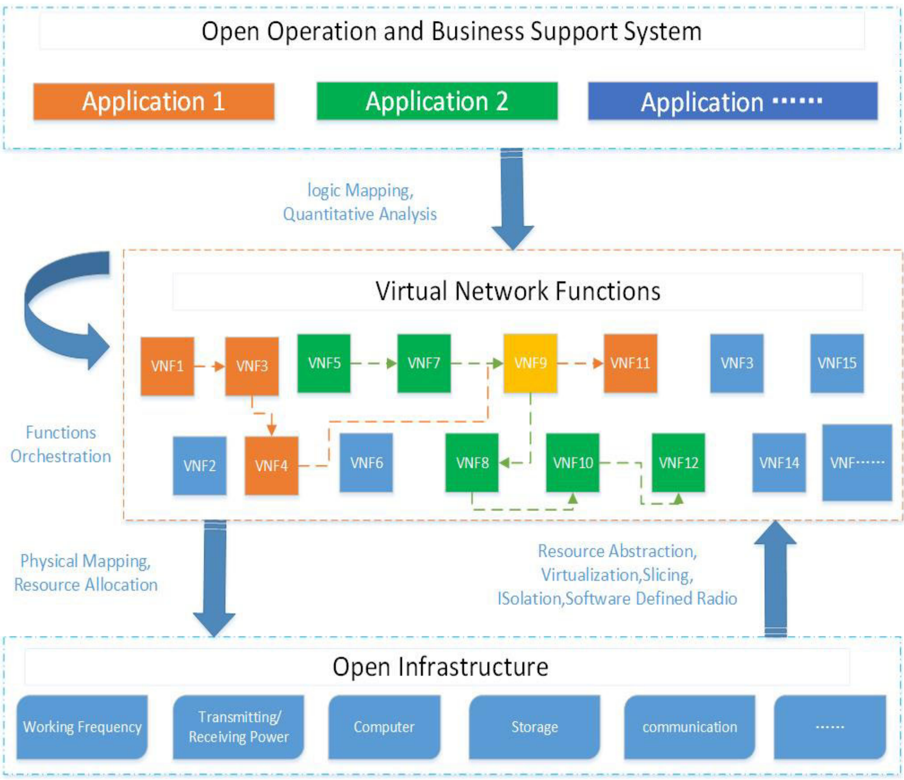

Figure 1. Concept of a ubiquitous radio network

2 Related Research

With the sprouting emergence of mobile internet and the increasing growth of mobile equipment, different applications have requirements for the underlying network in the aspects of safety, service quality and scalability; However, the current radio access framework could follow the development requirements of these applications which has become the urgent problem of 5G systematic framework [22]. There are two approaches to solve the framework problem of 5G systematic framework. One approach is the revolutionary, to level up and rebuild. The other one is tolerant to improve the current method, the radio access virtualization. Mobility First Future Internet Architecture (Mobility First wiki) in USA aims to design a completely new scheme to verify the future network framework including network framework design, quality evaluation, large-scale protocols and the application experiences of terminals. The research results of that will provide guidance for cellular network and network integration and will affect the technology standard of future network.

Mobility First wiki adopts a revolutionary way to rebuild a network system achieve the purpose of seamless integration. According to the reports of the market research institute ABI Research [22], the number of current infrastructure is tremendous and it can be seen that we have to take a great toll if we choose to revolutionize the next-generation radio access network.

Some other researchers have done research on 5G technology standard in the aspects of network evolution, integration and novelty, to support multi-parallel virtual network in public network infrastructure by abstracting, rebuilding and separating [9]. Each virtual network and make framework and protocol regarding the provided applications as if it could enjoy the physical network alone; it could also flexibly allocate the network resources in consideration of the dynamic change in network environment to realize the appropriate management and deployment of network resources. Virtual network could improve resource utility rate, service quality and network operation efficiency to efficiently reduce the cost of network operation and maintenance [10]. Network virtualization should abstract the functions of traditional network equipment of hardware to make network functions independent of hardware equipment [5, 23]. Stanford University proposes a Software Defined Network, SDN [11]. It is to do centralized control of network by separating the control and data in computer. SDN simplifies the network maintenance and improve the network efficiency. Meanwhile SDN could realize centralized control of separate network resources and shield details of underlying layer to realize the connection and integration of virtualized network functions. Li et al. from Bell Lab have discussed the benefits of introducing defined idea to radio network and provide a general framework and the definitions of each function [14]. Kempf et al. from Ericsson has proposed a tentative scheme to introduce software defined network to core network [15]. On the basis of that, Huawei has proposed Mobile Flow framework to rebuild the functions of core network [12]. Meanwhile, Mobile Flow framework completely separates the data transmission and control, and adds tunnel mechanism to switching equipment. It provides reliable guarantee and mobility management by the maintenance of tunnel; it realizes the centralized control of wireless based by the way of centralized baseband pool [16]. That framework is logically centralized and physically distributed, which separates centralized base-processing equipment from distant antenna RF units and connects them by high-speed RF exchange. Distant RF units are featured by high capacity and wild coverage network which is of high bandwidth and low latency. Baseband pool consists of good-quality processors which provide processing abilities for each virtual base. Actually, virtualization of mobile bases has become a case of function virtualization of network [24].

Although lots of researchers have done large amount of research on virtualized network mapping, the virtualized forms of radio network differ forms those of cable network (radio access network is not so stable, the base coverage of it is limited and radio mobile equipment can only be connected to the bases within signal range). It is of great significance not to copy the mapping approach of cable network to the radio access network. We have proposed an application recognized approach of virtualized access platforms to do logical mapping on applications and virtualized function set so as to make tailored service for applications in [7]. We also have done physical mapping on virtualized function set and infrastructure to maximize the usage of infrastructure [6, 17-18].

3 Architecture and Features of RSCMF

In this section, a framework with three main process is presented for mapping: infrastructure virtualization, logical mapping and physical mapping, as shown in Figure 2.

3.1 Infrastructure Virtualization

Infrastructure virtualization is the “0.5” layer. It virtualizes those hardware such as CPU, memory, hard disk, communication resources, transceiver power resources, radio frequency resources, etc. on a full scale. Meanwhile, it should collect relevant resource status of hardware, manage and monitor physical hardware resources, and realize VNF liberalization (not depend on any hardware), as shown in the infrastructure

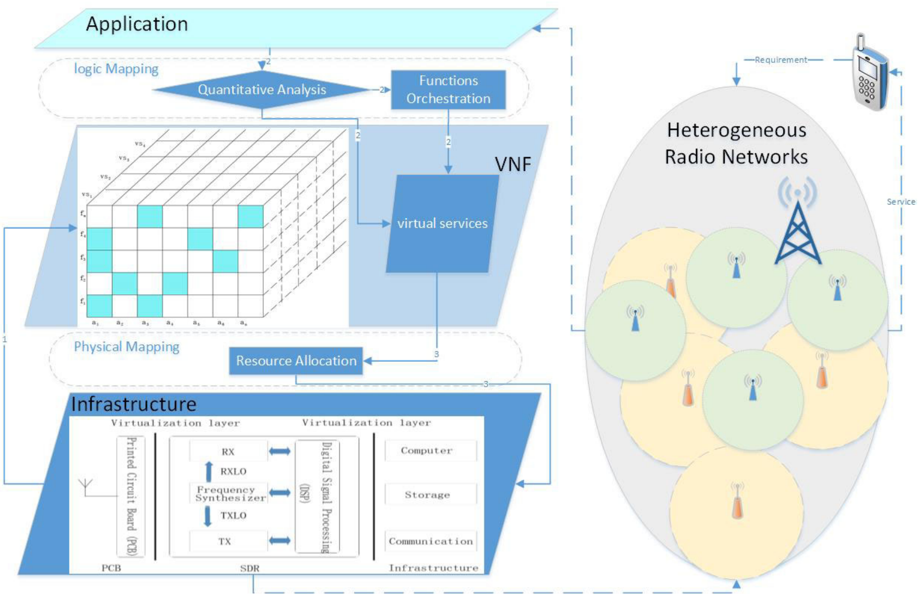

Figure 2. Mapping framework schematic of radio access network

part of Figure 2. Every functional module has an agent. The agent has its dependent control part and has its public control part. On the one hand, the radio agent gathers link and channel statistics from lower layers and export the statistics to the local and global managers. On the other hand, the radio agent exposes the functions of the virtual resource to the local manager.

To support such flexibility of functional module of hardware or software protocol, we need to build a software abstraction layer that decouples the tight connection between the PHY and the hardware front-end, with virtualization technology. This layer allows to provide a function f of specific attribute a that can be programmed by the control signaling which uses the radio agent interfaces. For example, the virtual baseband is abstracted by the underlay baseband dynamics and modifiers the RF front-end for a given channelization configuration specified by the control signaling. The virtual transceiver power is abstracted by carrier aggregation technology and antenna reconfigurations.

To support the sharing of the hardware and software resources, we have designed virtual service (VS), with SDR among the various agents. VS is the parameter set of QoS between virtual base stations and terminals, including uplink, downlink, and one or many of the service streams of the connecting from point to point. To guarantee segregation, tailored needs of users and resource utilization rate, cover and bearing separation technology have been used. We are to equip control functions RRH with high emission power to achieve large-scale coverage, to equip data functions with low emission power to realize high frequency usage. Terminals make use of double and multi-connecting framework to connect control with data RRH, and to achieve coverage and data separation by flexible deployment and control. All the VS could share VNF on platforms and could design all the needed VNF according to different scenarios and business demands.

3.2 Logic Mapping

Logical mapping is to abstract the information of applications in the real world into multiple logic data structures based on the views of different users. Every logic data structure is a user view and describes the functions users are concerned about. When the application changes, there is no need to change VNF and the physical resources of lower layer. The proper performance of applications could be guaranteed only by altering the mapping between applications and VNFs, as shown in the VNF and logical mapping part of Figure 2. So, logical mapping provides the precondition for the rapid deployment of new application.

To support the tailor of applications, we have designed a QADT for applications. To avoid curse of dimensionality due to the large number of functions of specific attribute $f_i a_j$ and to reduce the complexity of tasks, we reduce the dimensionality of $f_i a_j$ with squared error as loss function and in consideration of linear regression model. Then we categorize each attribute a_j by similarity, so that the similarity between the elements of the same type is stronger than that between the elements of different types. Our aim is to maximize the similarity between the same elements and maximize the differences between different elements. The main reason is that samples in the same data set should be alike while samples in different data sets should not be alike. Then information entropy is used to describe the purity of attribute a_j and to decide the priority level of attribute a_j. When the priority level of attribute a_j is the highest, attribute a_j is the root node of the decision tree for quantitative analysis. Similarly, previous operations on each branch node could gain the final decision tree for application quantitative analysis.

To support the rapid deployment of new application, we have designed a VFO method. Based on the requirements of real network construction, first we adopt VNFs as basic elements for arrangements. Second, we choose the modules satisfying requirements of those VNFs and the service cost of constructing VS by those modules is the lowest; then those service units are combined, arranged and connected in determined ways to form radio access service channel. After the orchestration we could satisfy the capacity of quick move, dynamic modification, reuse which are the requirements of automatic deployment.

3.3 Physical Mapping

Physical mapping is the process of allocating relevant resources into physical equipment. It consists of features of equipment, physical order of each function, the connection among the functional physical equipment, the associated of each physical equipment, link technology of each function etc. Its aim is to maintain the openness of infrastructure. Just the alterations of physical mapping can make it adapt to the dynamic change of infrastructure.

We put a resource collaborating mapping method to improve the utilization rate of resources and reduce the waste of energy, when the base stations are not in the peak [6]. First, we divide virtual cells based on the virtualized resource mapping features. Then through the constant iteration of base station mapping and radio link mapping, on the premise of guaranteeing QoS, we find the least amount of active base stations to serve the users, and put other base stations to sleep for energy saving.

For the win-win, we have proposed virtualization resources multi-objective mapping method in radio heterogeneous access networks [7]. This approach dynamically adjusts the weight value of objective functions in the multi-object mapping mathematic model of radio heterogeneous access by machine learning to balance the value of multi-users and to achieve the win-win result.

4 Case Studies: Resource Mapping in RSCMF

In this section, we show the benefits of exploiting resource mapping in RSCMF through two studies that realize scalable collaboration and dynamic change of topology, respectively.

4.1 Scalable Collaboration

We have done some initial investigations on scalable collaboration of radio communication resource by resource mapping of LTE's two different working modes: TDD and FDD. In the current network, the slot time proportioning of TDD-LTE is UL:DL=1:3. FDD-LTE allocates the symmetrical frequency of uplink and downlink. So, it makes the former more suitable for asymmetrical applications and the latter more suitable for symmetrical business. However, in the currently, applications distribution is not proportional and the needs of uplink and downlink are not the same, such as voice application, video stream application, FTP application. For TDD or FDD alone, the use of a certain network will result in pseudo congestion: in one direction the load is heavy while in the other direction that load is very light with efficient available resources.

Algorithm 1 Search of QADT algorithm

Input: $B = \{b_1, b_2, \ldots, b_n\}$, $QadtTree$

Output: vs_k

```
Search QADT(B, QadtTree)
node=QadtTree
if b_i == node.name then
  for node → v_{j=1}; node → v_{j=e}; j++ do
    if node → v_j ∉ VS then
      if b_i.value ∈ node → v_j.value then
        Search QADT(B − b_i, node → v_j)
      end if
    else
      return vs_k
    end if
  end for
end if
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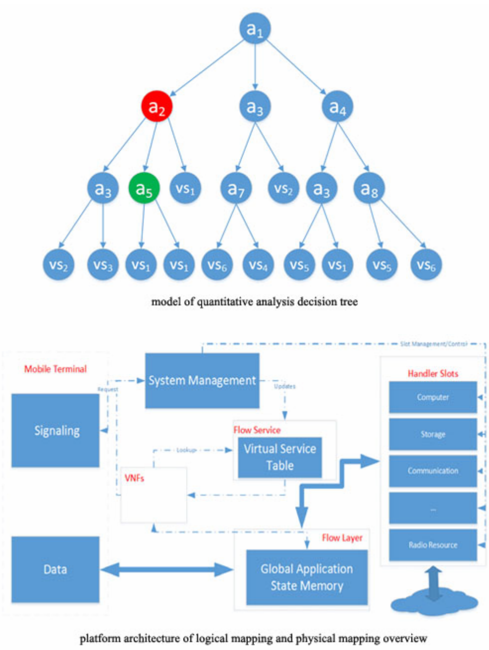

Figure 3. Logical mapping and physical mapping overview

For the previous problem, RSCMF maximizes the resource utilization rate by resource mapping in the overlapping area of LTE's TDD and FDD. The main function of each VS include: bandwidth of uplink and downlink, DSP, precedence, delay, reliability, peak mean, and so on. Each functional match infrastructure, spectrum, transceiver power of antenna, computing, storage, communication and other resources. Network management experts, according to the distribution of the application and the usage of infrastructure in the area, orchestrate various virtualization component into VS for establishing a customized application. Two goals will be achieved by orchestrating virtualization network functions: tailed application functions and the maximized economic benefits of infrastructure. Set the ingredients of signaling (Packet Data Protocol) is $B=\{b_1,b_2,\cdots,b_n\}$. Set the ingredients of VS is $vs_i=\{f_1,f_2,\cdots,f_n\}$. So, VS orchestrated by

$$\begin{aligned} obj \quad & \min\sum_{i=1}^{\Omega_f}\sum_{j=1}^{\Omega_a}\mu_{i,j}\times\delta_{i,j} \\ s.t. \quad & N\times f_{i,j}\rightarrow value\geq b_i\rightarrow value \\ & \forall\delta_{i,j}=1,\quad \exists\delta_{i+x,j}=1 \quad if \quad f_i\gg f_{i+x} \\ & \forall\delta_{i,j}=1,\quad \exists\delta_{i+x,j}=0 \quad if \quad f_i\neq f_{i+x} \end{aligned} \tag{1}$$

Ω_f is all functional modules, and Ω_a is all attribute of functional module. $\mu_{i,j}$ is the cost of the j^th^ attribute of i^th^ the functional module. $\delta_{i,j}$ represents that the j^th^ attribute of the i^th^ functional module is selected. $N\times f_{i,j}\rightarrow value$ represents that the value of the selected functional module f_i and attribute a_j is greater than or equal to the value of attribute b_i of the request signaling. N is the functional module $f_{i,j}$ number of one application needs. It is dependencies between modules and module. So, set $f_i\gg f_{i+x}$ represents that f_i is selected, then f_{i+x} is selected. Meanwhile $f_i\neq f_{i+x}$ represents that f_i is selected, then f_{i+x} isn't selected. Multiple function modules can be selected at the same time, so $\mu_{i,j}$ is given by

$$\mu_{i,j}=\begin{cases}\mu_{i,j} & N=1\\ N\times\mu_{i,j}+(N-1)\times\cos t_{i,j} & N>1\\ 0 & other\end{cases}$$

$\cos t_{i,j}$ is the cost of two functional modules $f_{i,j}$ combination.

First RSCMF does logical mapping on applications and establishes corresponding VS vs_i, as shown in Figure 3. Starting from the root node of the QADT, the node's name corresponding and the field name of the application request. If the value of the field belongs to QADT node subdomains, put QADT node subdomains recursive processing, until find the corresponding virtual service. The pseudo code of logical mapping of are given by "Algorithm 1" in Figure 3. The identification processes of applications are shown "model of quantitative analysis decision tree" in Figure 3. First of all, to match a_1 and b_1; If the value of b_1 belongs to between the value of a_1 to a_2, then to match a_2 and b_2; Finally, until we has find vs_1.

$$\begin{aligned} obj \quad & \min F(X)=\sum_{j=1}^{n}\Gamma_j\times F^j(X) \\ s.t. \quad & vs^s\leq bs^{sH} \\ & \forall position_i\in vs,\quad \exists position_i\in\sum bs^{sH} \\ & \sum vs^s\leq\sum bs^{sH} \\ & bs^{ca}\leq bs^{cH} \end{aligned} \tag{3}$$

Then, RSCMF does physical mapping that is radio spectrum resources allocation to corresponding node of TDD or FDD. Physical mapping contains two stages. In the first stage, the nodes of approximately minimum number are decided to cover relevant area to make sure that the need of any mobile terminal could be satisfied. In the second stage, wireless resources are mapped to guarantee that users' QoS could be satisfied and wireless resources could be managed by nodes. As network traffic has tidal problems, focus on the optimization objectives of different types of mobile traffic are different.

The processing flow of physical mapping on vs_i is given by (3). Where $F^j(X)$ is a single-objective function, and $\Gamma=\{\Gamma_1,\Gamma_2,\cdots\}$ is the active state space set for the weights of the objective functions. Meanwhile, at any place position $position_i$, if there is a VS $position_i\in vs$, so there must be physical nodes $position_i\in\sum bs^{sH}$ and the matching. bs^{sH} is the biggest covered area of nodes. The obtained wireless resources of VS bs^{ca} should be less than or equal to the maximum processing capacity of node bs^{cH}. This process of logical mapping and physical mapping are shown in Figure 3. Which employing reconfigurable computing for the application level (OSI Layer 7) to transport layer (OSI Layer 4), as well as associated development tools that allow networking domain experts to easily customize the system.

Finally, we carry out collaborative communication of uplink and downlink or the nodes of TDD and FDD. The collaborative communication of vs_i is given by

$$\begin{aligned} \sum_{i=0}^{n}vs_i.up &= \sum_{i=0}^{n}\omega_{i,1}\times Tdd.up+\sum_{i=0}^{n}\omega_{i,2}\times Fdd.up \\ \sum_{i=0}^{n}vs_i.down &= \sum_{i=0}^{n}\omega_{i,3}\times Tdd.down+\sum_{i=0}^{n}\omega_{i,4}\times Fdd.down \end{aligned} \tag{4}$$

$vs_i.up$ is the uplink PRB resources number of vs_i. $vs_i.down$ is the downlink PRB resources number of vs_i. $Tdd.up$ or $Tdd.down$ is 1 PRB resources of TDD-LTE. $Fdd.up$ or $Fdd.down$ is 1 PRB resources of FDD-LTE. PRB resources of TDD-LTE equivalent to PRB resources of FDD-LTE. So, the all PRB resources number of vs_i is less than or equal to the PRB resources number sum of FDD-LTE and TDD-LTE. Due to the slot time proportioning of TDD-LTE is UL:DL=1:3, $\sum_{i=0}^{n}\omega_{i,1}$ is less than or equal to 1/4 PRB resources number of TDD-LTE, and $\sum_{i=0}^{n}\omega_{i,3}$ is less than or equal to 3/4 PRB resources number of TDD-LTE. Due to the slot time proportioning of FDD-LTE is UL:DL=1:1, $\sum_{i=0}^{n}\omega_{i,2}$ and $\sum_{i=0}^{n}\omega_{i,4}$ are less than or equal to 1/2 PRB resources number of FDD-LTE.

FDD and TDD in Figure 4 display the resource allocation when LTE-FDD or LTE-TDD is used alone. FTDD is the automatic optimal resource allocation according to the proportion of the uplink of resource to the downlink of resource. RSCMF is the resource mapping of the frame in this paper. From the subgraph a, b of Figure 4, it can be seen that the pseudo congestion of uplink emerges in FDD and the pseudo congestion of downlink emerges in TDD. Although FTDD could improve this, the use rate of the total resources is only about 70%. RSCMF framework could increase the use rate of the total resources to above 95%. It also can be seen from the subgraph d and e in of Figure 4 that FTDD approach is superior to FDD and TDD in the aspects of application lost and resource allocation, but not as good as RSCMF framework.

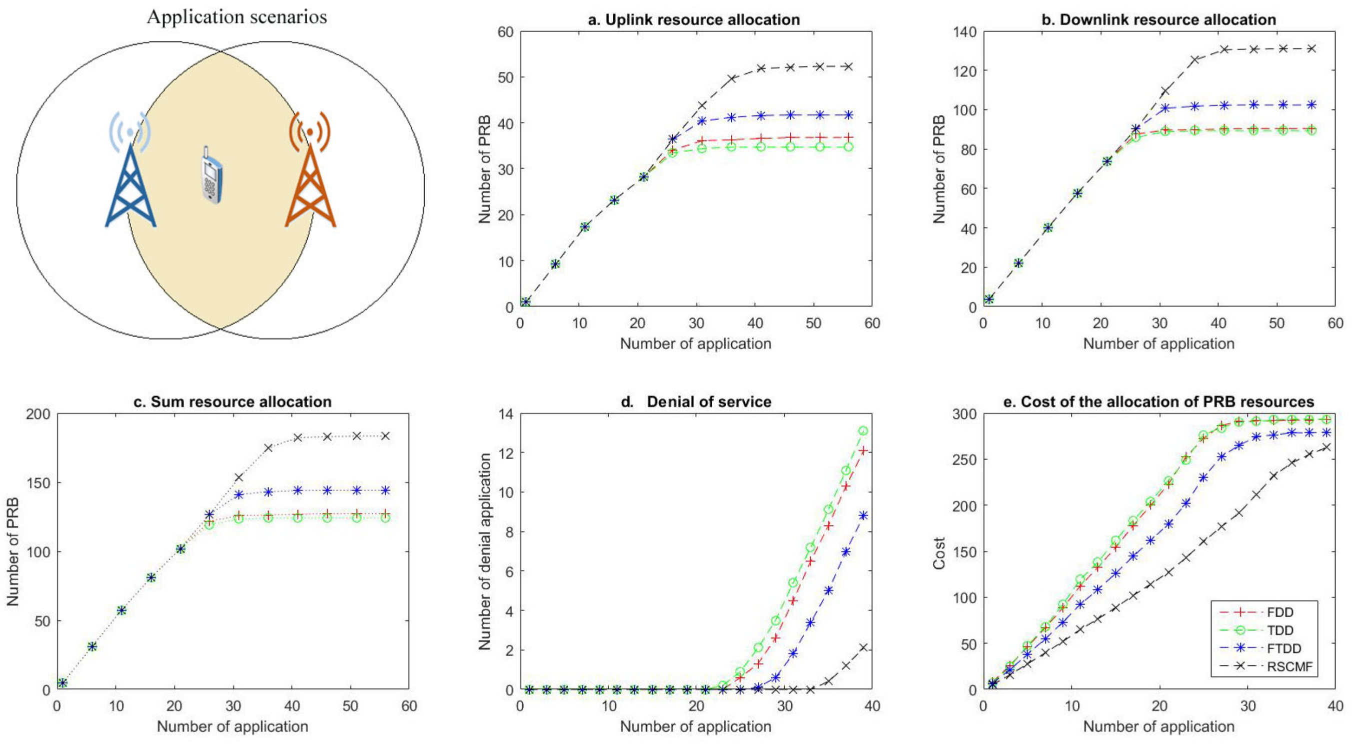

Figure 4. In the time, there are in total 200 PRB resources in the base stations of LTE-TDD and LTE-FDD. Applications include voice, FTP, video, file download and interactive types, with occurrence probability 0.3, 0.04, 0.31, 0.15, 0.2 respectively and uplink to downlink 1:1, 9:1, 1:5, 1:8, 1:2 respectively.

4.2 Dynamic Change of Topology

As current network is designed for the load of peak, this leads to the shortage of resource use of the bases station and the waste of energy. In super-dense network environment, we have done research on the features of RSCMF framework when sleeping nodes and topology structure change in non-busy hour, as shown in Figure 5.

When node "A" loses efficacy suddenly, systems can automatically detect the load of active nodes "B", "C", "D" and "E". If one or many active nodes of "B", "C", "D", "E" could bear the load of nodes "A", the load of node "A" will be taken to relevant nodes. If the active nodes could not bear the load of "A", the nodes near node "A" will be awaken to bear the load with active nodes [6]. It can be seen from Figure 5(a) that active nodes "B", "C", "D", "E" could bear the load of node "A", indicating that RSCMF framework could adopt to the dynamic change of low topology structure without affecting service.

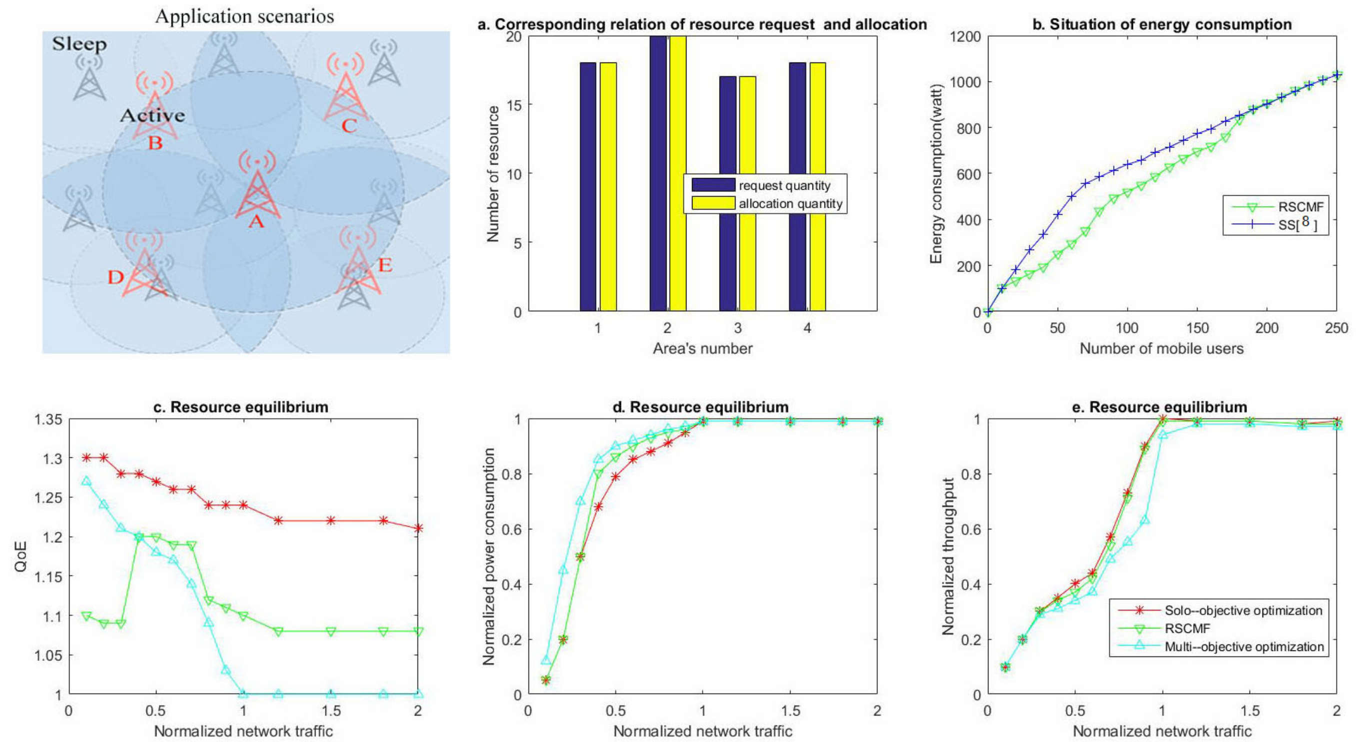

Figure 5. (a) is the load share of node A when node A lose efficacy suddenly. (b) shows that sleeping nodes realizes system efficiency in non-busy hour when QoS is satisfied. (c), (d) and e show that RSCMF framework realize the balance of users under different load

RSCMF framework dynamically divide virtual cells according to the network topology change and the resource demanding amount of logical mapping. On the premise of guaranteeing QoS, the active base stations and radio resource are updated by iteration mapping. So, we make use of least active bases serve the users and sleep other bases in network to gain energy efficient purpose. It can be seen from Figure 5(b). Compared with single node sleeping strategy (SS) in [8], RSCMF framework could save more energy in non-busy hour [6].

Physical mapping is a co-optimized problem of multi-object system in essence. As for the problem of multi-object optimization, the results differ a lot because of the different preference of decision objective and the different importance of target decision makers. RSCMF intensively learn the weight values of each objective to make the value of multi-optimization close to the value of single optimization. It can be seen form Figure 5(c), Figure 5(d), Figure 5(e) that when network load is low, RSCMF framework tries to make system energy efficient on the premise of guaranteeing QoE. When the network load is medium, RSCMF prefers QoE. When the network load is high, RSCMF prefers internet throughput.

5 Conclusion

For the ease of constructing ubiquitous and open radio access systems with large-scale resource collaboration mapping, the conceptual framework called RSCMF is proposed. RSCMF is to guarantee infrastructure and application being open and independent. On the hand, aims to solve resource collaborative communication under the condition of low coupling between infrastructure and radio access systems, by virtualization and SDR. On the other hand, RSCMF can be made for the applications of related functions by logical mapping and physically mapping. The resource mapping in RSCMF is illustrated through examples based on our research efforts. RSCMF provides a customized service for various applications with resource collaboration. It can not only support the heterogeneous network platform for “the interconnectedness of all things” by virtual integration, but also provide differentiated services for various kinds of the applications. Whether it is the changes of infrastructure or application, you are only needed to change the way of mapping between them, then it can provide the customized services required.

The framework provided by us consists of two random information: status information of infrastructure and that of application queue. Status information of infrastructure indicates of prompt transmission of physical layer while status information of application queue indicates the emergency of application data flow. Thus, it is a problem of random optimization and it is a significant job to prove the stability of optimization. Our next research is to take the Lyapunov model to analyze the stability of RSCMF framework.

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