DJ Journal of Advances in Electronics and Communication Engineering, Vol. 1(2) 2015, pp. 1-11

RESEARCH ARTICLE

A Network Architecture using Super Base Station for Communication in Energy-Efficient Fifth-Generation Mobile Systems

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Received-5 October 2015, Revised- 1 November 2015, Accepted-11 November 2015, Published-27 November 2015

ABSTRACT

Nowadays communication through mobile and internet has become a main part of daily life. In order to satisfy the mobile data traffic request and to increase the network coverage and capacity the wireless service providers use a heterogeneous network with technologies of multiple access and base stations. The significance of base station as a wireless access point has gained a serious attention. Volumes of large data are being transported through the base station and are isolated from each other. This makes sharing and allocation of hardware and radio resources of dissimilar types almost impossible within the overall network. The wireless service providers are thus facing heavy network operational expenditures. Large system power consumption is another one important issue. In this paper, a centralized architecture for radio access network is put forward as a prospective solution for an energy-efficient fifth-generation mobile communication system which is mentioned to us the super Base Station (super BS). The physical entities and logical functions of conventional base stations are decoupled by super base stations and so different types of resources in a system can be multiplexed statistically and shared horizontally all over the system among all the active base stations.

Keywords: Heterogeneous network, Wireless access point, Radio resources, Communication systems, 5G.

1. INTRODUCTION

In order to facilitate the massive progress of tablets and mobile network applications, the wireless transmission data should be increased at a very rapid rate. Mobile users form the back bone of such an increase. It is expected that by 2019, Wi-Fi traffic will compose a major part which is almost 62.8% of the total global internet traffic excluding managed IP according to the statement of CISCO Visual Network Index (VNI). [1] The proportion of Wi-Fi is lesser for overall IP due to the availability of wired devices such as set-top unit, which creates IP VoD traffic.

[2] investigated the code assignment in the OFCDM system, intended to reduce the media control interface. To meet the explosive mobile data traffic demand, various measures have been taken such as smaller cells, more spectrum, retaining advanced wireless technologies such as Orthogonal Frequency Division Multiplexing (OFDM) and Multiple-Input Multiple-Output (MIMO). This improves the system capacity to a great extent. However, the peak data rate of 2G and 4G systems has only increased at a combined annual growth rate of 55% [1]. There is a wide gap between the traffic demand and capacity of network and the gap is getting wider day by day. [3] studied the exploitation of the number of traffic demand nodes whose essential rates are completely contented with an available budget. They generated an approximation algorithm that results in an (e - 1)/2e fraction of the optimum which not only offers quality-guaranteed solutions to the budgeted problem of cell planning but also emphasizes on planning a HetNet with limited capital expenditure. Primary numerical analyses show that small cells can improve the cellular system capacity considerably if they are properly planned. However, if the traditional mobile network architecture based on distributed Base Stations (BSs) is used, many BSs will be

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Double blind peer review under responsibility of DJ Publications
http://dx.doi.org/10.18831/djece.org/2015021001

needed, which pose more challenges to the mobile operators such as

- The assembly, maintenance and power consumption of a huge number of base stations causes a quick increase in the operational network costs.
- Owing to the thick deployment of BSs there is an acute inter-cell interference between the base stations without full cooperation as they are logically independent of each other.
- The architecture of each present network base station must be designed with a high capacity to support the maximum possible traffic load in its cell. Because of the hardware resources of the base station, the traffic load is low and most of the capacity is wasted including calculation and capacity of memory. Meanwhile they are isolated from each other and cannot be shared among different base stations.

[4] discussed about the prospective technologies of 5G with two major themes such as green and soft. By reconsidering the traditional cell-centric design and Shannon theorem, capacity of network can be largely increased while the power consumption of networks is decreased.

MCC combines cloud computing and the parameters of mobiles. They overcome barriers related to the performance such as storage, battery life, bandwidth and environment such as availability, heterogeneity, security and scalability as discussed in [5]. Moreover the future research guidelines of mobile cloud computing are also discussed. The fifth generation wireless communication systems are estimated to provide a growth in spectral and energy efficiency at least by a factor of 10, and the area throughput growth at least by a factor of 25. H-CRAN is presented [6] as the innovative paradigm of WAN, where mobile cloud computing is used to accomplish the centralized processing of large-scale cooperative suppressing interferences in co-channel. [7] explained the presently available optical technologies of fronthaul and started activities towards more effective and scalable solutions and result is given. It was found that 5G particular service properties may influence future networks of backhaul, midhaul, and fronthaul more actively. The framework of Cooperative Hierarchical Caching (CHC) in C-RAN is introduced in [8] where Base Band Unit (BBU) and the Radio Remote Heads (RRHs) are jointly cached by the contents. Unlike in traditional methods, the baseband unit cache, cloud cache, presented in [8] is a cache hierarchy layer, bridging the capacity gap between the traditional edge-based schemes of core-based caching.

In this article, it is presented a physically centralized architecture of mobile network, specified as the super Base Station (super BS), for the 5G mobile system. The baseband unit pool is created with arrays of Digital Signal Processors (DSPs). In the present communication system, programmable DSPs have been extensively used with the advantages such as low power consumption and high ability to handle processing at real-time. It is expected that in the DSP based system of super BS, an average power of 5–10 Watts per an LTE sub carrier can be reached in the baseband unit pool. When compared to GPP based BBU pool, a great challenge for super BS is managing all the hardware resources. This paper proposes a technique of processing-level real-time virtualization for the management of hardware resource in the super BS. The centralized resource management centre directly allocates system resources to these VBSs in a cooperative and efficient way, without any operating system interruption and also can be guaranteed the processing of real-time communication. Table A1 labels the key differences and the performance comparison between the C-RAN and super BS.

2. NETWORK ARCHITECTURE FOR 5G MOBILE SYSTEMS USING SUPER BASE STATION

Figure B1 shows the super BS using centralized network architecture. Alike C-RAN, it consists of three main parts. They are the distributed RRHs whose location is at the cell sites, the low dormant stage and highly efficient optical network and the super BS. Furthermore, the super BS is divided in to three more parts. They are the DSPs using high-performance multi-mode redesigned baseband unit pool, the General Purpose Processor (GPPs) using multi-mode higher layer Protocol Processing Unit (PPU) pool, and the Global Resource Management Centre (GRMC). The distributed Remote Radio Heads (RRHs) are arrays of antenna that contain processing units of multi-band Radio

Frequency (RF), which are organized exactly in the same way as the antennas in traditional base stations. The baseband unit pool is connected by all the remote radio heads through a high band width and low- dormant stage optical network and a radio frequency switch. The merely changing switch policy can be vigorously adjusted for the mapping between RRHs and BBUs under the control of the global centralized resource management centre.

Furthermore, according to the cell load, the configurations of RRHs can be adjusted by global centralized resource management centre and turn on or off switch of the remote radio heads to assure the coverage of network in an energy efficient way.

The main part of the new centralized architecture for 5G mobile systems is a super base station decoupled with the traditional base stations, logical functions and physical entities. Different types of hardware resources are horizontally shared. The technologies of resource pooling and real-time virtualization using the super BS provide a transparent summary for these hardware resources and transform them in to one or more logical entities. Therefore, these entities can be easily built up by one or more VBSs with different standards and through a united and open interface.

In the super base station, the baseband unit pool of high-performance multi-mode reconfigurable type consists of large scale programmable arrays of DSP, which constitute the procedures of physical layer processing. The PPU pool of multi-mode higher layer refers to a resource pool for higher processing of layer protocol such as over the air interface for layer 2 and layer 3. The Power PC, ARM processors and x86 servers are the large scale GPP platforms for the PPU pool, so that the software programs running on GPPs are implemented by the higher layer protocol functionalities. The exchange of the huge protocol data between the pools for PPU and BBU uses high-speed 10-GbE.

The global centralized resource management centre is the super BS system control centre. It defines the radio and hardware resources allocation to each VBS.

Under the Global Centralized Resource Management Centre (GRMC) control, according to their traffic load profiles, the resources especially hardware can be allocated dynamically to different VBSs, which maximize the utilization of hardware resources. By the allocation of joint radio resource and hardware resource in cooperative ways different types of system resources can be managed, where an energy-efficient wireless network can be realized.

3. CENTRAL TECHNOLOGIES

In the super BS, the key challenges are to efficiently build the resource pool such as the pool for BBU and PPU, where an interconnection of high-bandwidth and low-latency provide the different hardware resources.

3.1. Large scale resource pooling in super BS

There is no static mapping between the hardware resources and VBSs in super base station systems. BBUs and PPUs of large quantities are physically grouped together and form the BBU pools and PPU pools, which implement the statistical multiplexing and cooperative allotment for different resources. Note that in present systems of mobile communication, the RRH and BBU functions are separated by their BS products, where the procedures for a physical layer from BSs group are treated in a small size baseband unit pool. Additionally, between different BBUs and PPUs a large amount of data needs to be exchanged within a millisecond time period. When constructing the resource pool, the bandwidth and data exchange dormant stage among the BBUs and PPUs are the two most critical limitations.

Figure B2 shows a framework for 4-layer interconnection proposed in the super BS to build the BBU pools and PPU pools. Based on the open Micro-Telecom Computing Architecture (MTCA) and Advanced Telecom Computing Architecture (ATCA), through PCIe interface a given number of BBUs/PPUs are first connected to a BBU/PPU board.

Through the plane of GbE, various high-speed back BBU/PPU boards are then joined to each other and form the BBU/PPU sub-pool. Finally, many BBU/ PPU sub-pools are constructed through a 10GbE optical fibre network where a huge number of air interface protocol data can be swapped between different sub- pools. Furthermore, by using this open framework, the operators of network can easily raise the capacity of schemes by simply building and introducing new resource pools in the system, without any intervention to the services of current network.

3.2. Integration of large scale resource pool

It is important to retain the integration among base stations in mobile communication systems. The traditional base station systems can achieve both integration of frequency and time and ensure the long-term stability of their clock frequencies by synchronization to GPS signals with their respective local clocks. However, the GPS method of integration has numerous problems, such as the particular necessities of GPS antenna on installation environment and a high rate of failure. In addition, it cannot support remote maintenance. The clock integration in a high-speed local area network is provided by Precision Time Protocol (PTP) based IEEE 1588 [9], and for precision time integration, one pulse per second (PPS) and time of day (ToD) time interface is used [10]. In this paper, it is proposed a super BS with the mechanism of two-layer integration, where all the units of the system hardware receive the same input of clock signal. In the first layer, the GPS is first synchronized by centralized Clock Distribute Unit (CDU). Then the CDU creates a synchronous one pulse per second reference signal and in the resource pool, transfers the signal to all the hardware units. In the second layer, each hardware, i.e., the BBU or PPU has a clock agent. Once the synchronous reference signal is received from the CDU, the clock agent will first calculate from the CDU, the delay in circuit level transmission to its master hardware resources. On the basis of the received synchronous reference signal and the transmission compensation of delay, all the resource pools hardware units are coordinated to the CDU.

3.3. Super BS in 4-layer real-time virtualization

The technologies of virtualization could be realized using large scale BBU and PPU pools with high-speed. Interconnections of low- latency implement the global resource sharing among diverse virtual base stations in the super BS. With virtualization, a hardware resource's obvious gist is provided and transformed into one or more versions logically that can be used by dissimilar virtual base stations, while the services supplied to the end users are exactly in the same way as traditional base stations [10, 11, 12]. Note that in the C-RAN and WNC, the virtualization resource is realized through IT-based traditional methods, such as hypervisor providing services Xen and Vmware [12]. These systems decoupled and shared the software and hardware resources based on the operating system. An abstraction layer of operating system is created from different VBSs, to manage the processing requests although creating tasks from dissimilar VBSs will cause high system operational cost and extra processing dormant stage [13], where the requirement of critical data processing dormant stage in wireless communication is hard to be guaranteed [5].

Figure B3 shows the framework of super BS in four layer real time virtualization. It consists of hardware resource layer, virtual base station layer, virtual resource layer and virtual network application layer from bottom to top. The GRMC directly control all these layers without the operating system abstraction layer participation. The dissimilar types of hardware devices are decoupled in the hardware resource layer and there is an entity in hardware resource abstraction which is used to manage the corresponding device on top of each device. Hence various kinds of hardware resources can be directly scheduled without the operating system interference. As a result the loss in resource and system operational tarriance during the hardware resources scheduling are minimized. In the virtual resource layer, the resource mapping between the hardware resources and virtual resource pool is maintained. The virtual base station layer is responsible for a programmable and reconfigurable interface in connection with the operators of virtual network such as the virtual global system for mobile communications, third generation and long term evolution network operators, who can easily provide dissimilar services of network based on the end users requirement. Under this framework of 4-layer virtualization, the operators of network no longer need to provide attention on the hardware resources. They need to emphasize only on the use of virtual base station layer. In the lower layers, all VBSs can use and share the hardware resources. Thus the resource application is greatly improved.

A scheme of seamless online resource migration is proposed in the super BS based on the Radio Network Controller (RNC) relocation process in networks of mobile communication and the migration of traditional virtual machine in computer networks. The process of resource migration is to logically separate the processing task and data context which is the main idea. The processing task is the procedure of higher layer, (e.g) the process of turbo encoding/ decoding. During the procedure, the data framework is consistent with the information of computing. Figure B4 depicts that, when global centralized resource management centre initiates source migration operation for the BBU or PPU processing task (a), it first stops using hardware resource 1 and the context of data is transmitted to hardware resource 2. After that, a corresponding processing task of BBU or PPU (a) is re-built on hardware resource 2. The resource mapping for the virtual resource 1 is updated by virtual resource layer and frameworks it to hardware resource 2. The hardware resource 1 is generated that added data context during the procedure of resource migration. It is further transmitted to hardware resource 2 to confirm the seamless data transfer and the correct order of data information. Then the processing task of BBU or PPU (a) is terminated and hardware resource 1 withdraws all the related resources. Finally, the new processing of BBU or PPU task (a) is re-built and completes the procedure of resource migration for the virtual resource 1.

3.4. Need of acceptance hardware resource allocation

The consequence of network traffic tide [14] can be effectively solved and the utilization of hardware resource can be maximized in adaptive hardware resource allocation. Furthermore to save power, some hardware resources can be turned off when the system is in a low traffic load. The main aim of the hardware resource allocation is to maximize the utilization of hardware resources according to the system traffic load dynamics by finding an optimal mapping between the BBU pool /PPU pool and the VBSs. When changes in the system traffic load distribution occurs, accordingly the mapping of hardware resource between the BBU/PPU pool and the VBSs is changed, so that the network traffic tide-effect is modified and maximizes the hardware resource utilization.

The proposed semi-static resource allocation scheme with Load Diversity (LDA) is used to fully exploit the diversity of traffic load and avoid the adjustment in recurrent global system resource. [15] To map the virtual base stations covering distant cells to the same BBU/PPU sub-pool is the key idea of the LDA system. When changes in the virtual base stations traffic loads are carried out, the virtual base stations resource allocation that are mapped to the same BBU/PPU sub-pool is adjusted with a greater importance. If the residual hardware resources on that particular BBU/ PPU sub-pool cannot satisfy the requirement of its serving virtual base stations, then new BBU/PPU sub-pools are allocated and the new BBU/ PPU sub-pool is migrated by virtual base stations with a high traffic load. The resource mapping between the BBUs/PPUs and the virtual base stations can be converted to an a bin-packing problem within a given BBU/PPU sub-pool and heuristic algorithms can be employed to solve this problem.

Figure B5 shows the proposed LDA system comparison of the consumption of system energy in the baseband unit pool with that of the fixed resource allocation in regular cellular networks in a workday with 50 cells. Hence the proposed system considerably cuts the power consumption of a system compared to the fixed resource allocation method in regular cellular networks. The proposed LDA system power consumption is somewhat higher than the scheme of optimal resource allocation under high system traffic load situations.

4. CONCLUSION

Future 5G mobile systems will be a vast network, coexistent of access technologies and supply high- services of bandwidth to end users. However, multi-mode wireless access points dense deployment will cause an increased cost of network operations, high power consumption and low resource utilization. The architecture of centralized system is a promising solution for the above tasks. In this paper, the proposed super BS used logically distributed but physically centralized architecture of a new network. They horizontally shared different types of system resources among all virtual base stations through the method of resource pooling. A framework of 4-layer real-time virtualization is presented in communication networks to guarantee the real-time processing. Finally, a scheme of hardware resource allocation with load diversity, where the hardware resources can be allocated dynamically to dissimilar virtual base stations according to their profiles of traffic load is introduced. As a result under the architecture of a super BS system, BBU/PPU pool power consumption is greatly reduced and utilization of system hardware resources is improved substantially.

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APPENDIX A

Table A1.Comparison between main techniques and performance of C-RAN, super BS.

Items	Centralized Radio Access Network	Super Base Station
Components of Base Band Unit	Platform of General Purpose Processor with hardware accelerator	Digital Signal Processor Reconfigurable
Technique of Virtualization	Traditional IT-based virtualization	A process level virtualization
Performance/Watt	Low	High
Performance of Real time	Low	High
The interface openness	High	Low

APPENDIX B

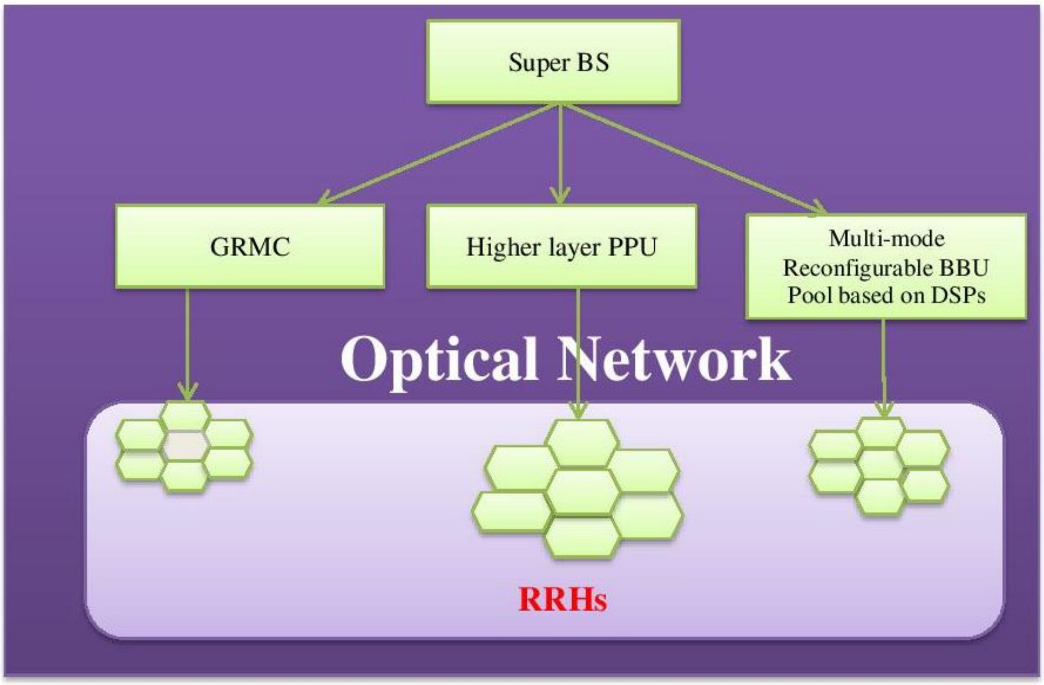

Figure B1.Centralized network architecture based on super BS

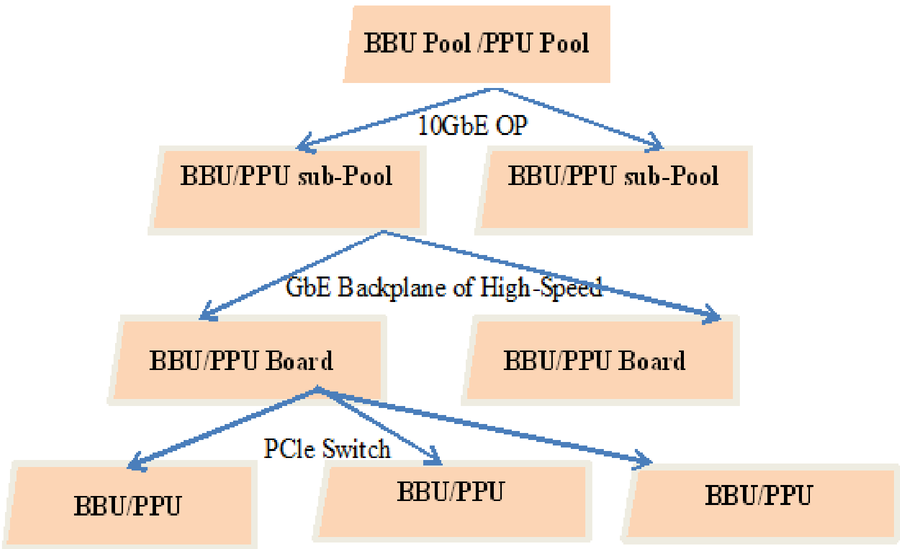

Figure B2.Framework for super BS resource pooling

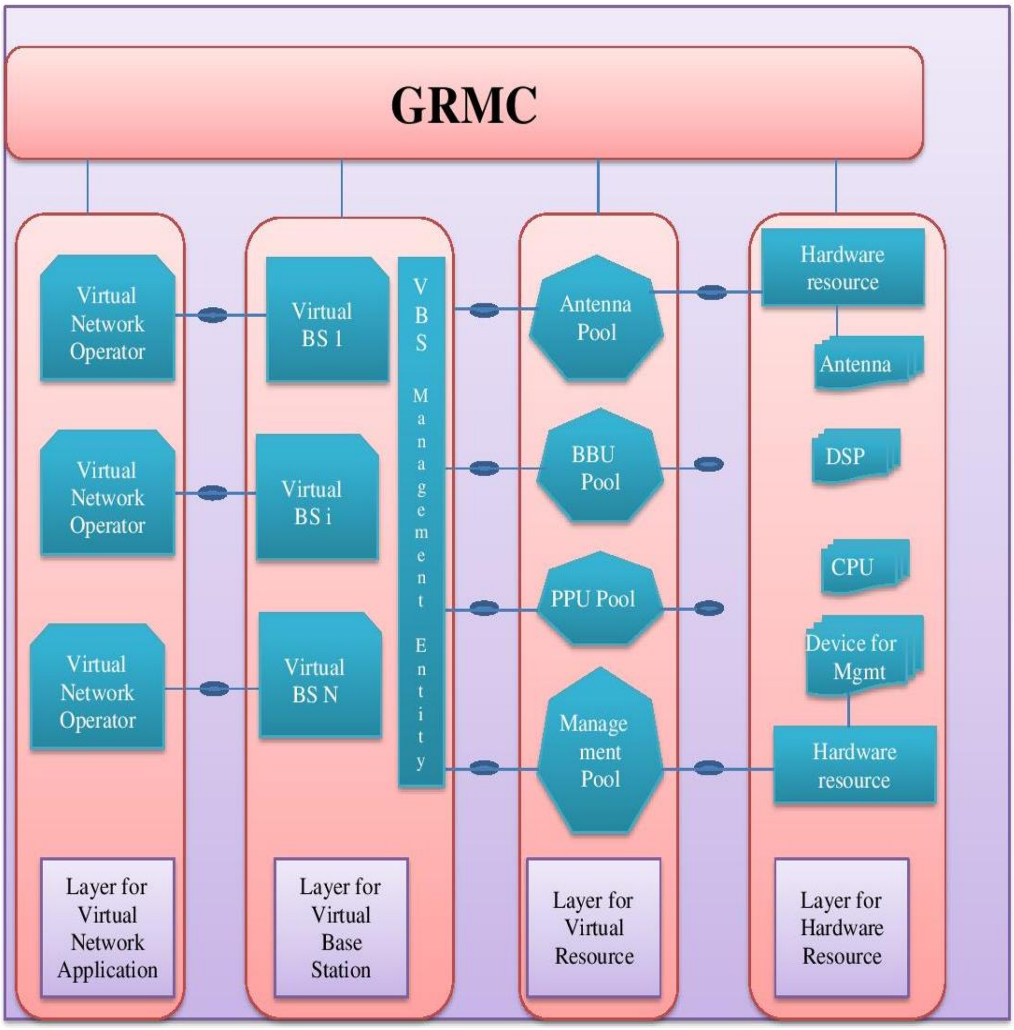

Figure B3.Structure for the Super BS in real-time virtualization

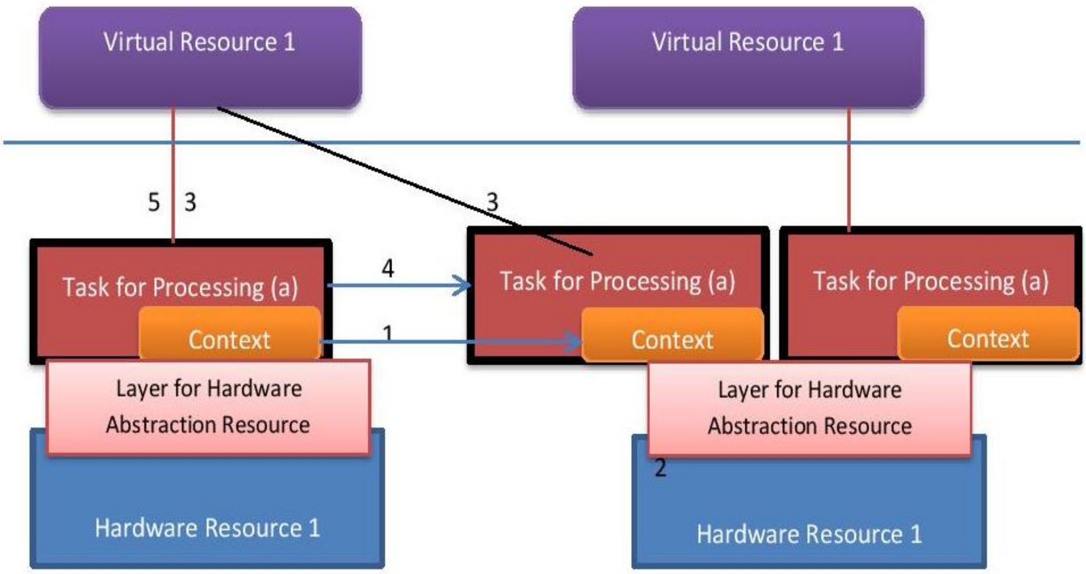

Figure B4.Super BS for seamless online resource migration

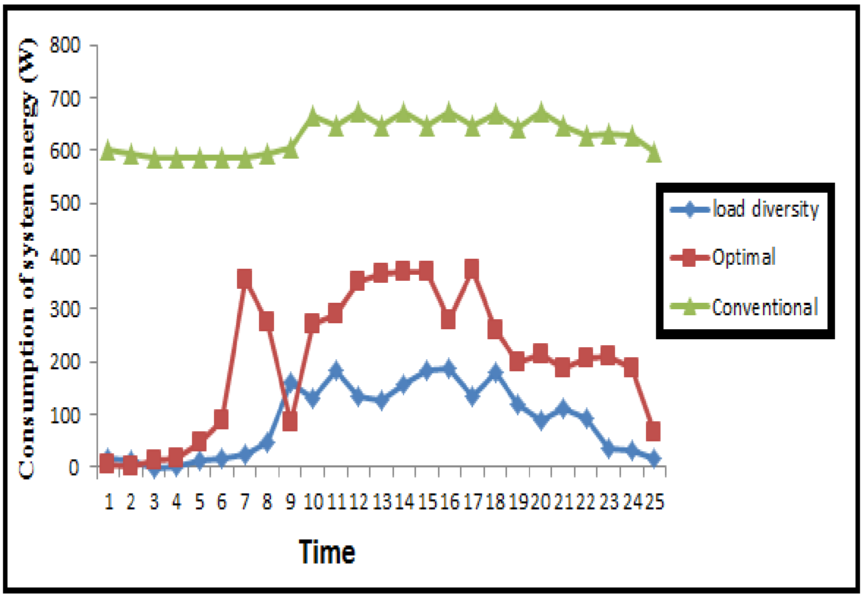

Figure B5.Comparison between consumption of system energy and time under small super BS