An Integrated Approach for Future RAN Architecture

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***Abstract*—In this article, we identify and study the potential of an integrated deployment solution for energy efficient cellular networks combining the strengths of two very active currently research themes: software defined radio access networks (SD-RAN) and decoupled signaling and data transmissions, or beyond cellular green generation (BCG2) architecture, for enhanced energy efficiency. While SD-RAN envisions a decoupled centralized control plane and data forwarding plane for flexible control, the BCG2 architecture calls for decoupling coverage from capacity and coverage is provided through always-on low-power signaling node for a larger geographical area; capacity is catered by various on-demand data nodes for maximum energy efficiency. In this paper, we identify that a combined approach bringing in both specifications together can, not only achieve greater benefits, but also facilitates the faster realization of both technologies. We propose the idea and design of a signaling controller which acts as a signaling node to provide always-on coverage, consuming low power, and at the same time also hosts the control plane functions for the SD-RAN through a general purpose processing platform. Phantom cell concept is also a similar idea where a normal macro cell provides interference control to densely deployed small cells, although, our initial results show that the integrated architecture has much greater potential of energy savings in comparison to phantom cells.**

Keywords*—*5G wireless networks, Energy efficiency, mobile communications, radio access networks, software defined networking.

I. Introduction

Mobile communication systems witnessed growth at a much slower pace than the user-end devices mainly due to inflexible and expensive equipment, complex control plane protocols, and vendor specific configuration interfaces. Software defined networking (SDN) suggests hardware agnostic programmable platform for development of protocols, applications, etc., hiding all complexity of execution through separation of control and data plane [3]. This decoupling will introduce unparalleled flexibility for innovation and future growth and will also reduce CAPEX and OPEX through ideas like network virtualization. Moreover, with the growth in user data, more and more base stations (BSs), currently consuming over 80% of the total network energy [1], are added into the system substantially increasing the energy consumption and carbon footprint of cellular networks. The state-of-the-art energy management schemes exploit the redundant capacity during the low traffic scenarios and put a fraction of the BSs in sleep mode. However, they might cause coverage holes and in order to achieve the real benefits of energy management, it is needed to separate capacity and coverage via logical decoupling of the data and control or signaling transmissions in the future systems, also known as BCG2 or cell on-demand architecture [1]. The signaling nodes provide coverage and always-on connectivity and will be designed for low rate services, for system access and paging, consuming very small fraction of power; whereas the data nodes can only be used on-demand depending on the traffic. The decoupling is expected to provide 85-90% energy saving potential compared to the current systems [2]. Although, both of the approaches have different technical objectives, i.e., SDN focuses on inducing flexibility through programmable hardware and BCG2 architecture tries to get linear relationship between energy consumption and user traffic. The end goal, however, has a lot in common in terms of physical realization. The centralized controller in the state-of-the-art proposals of SD-RAN, either resides in the core network or in a centralized data centre [3], an idea migrated from Cloud RAN (Radio Access Network). We argue that the signaling node providing coverage and system access can also be a suitable host for the centralized controller, or virtual big BS of [3], in SD-RAN containing major functionalities of control plane, such as, coordination and resource allocation, for a number of BSs in a geographical area. In this paper, we present the idea of a signaling controller which provides always-on system access, contains control plane functionalities of interference management, resource allocation, etc. Since, the control plane can be implemented using general purpose processors; the signaling node does not need additional power consuming elements and can still conform to the low-power consumption attribute as required by the BCG2 architecture. The signaling controller can use dedicated microwave links to connect to the BSs in its coverage area or fibre if cost-effective. Moreover, SDN can also be viewed as the enabling technology for BCG2 architecture. Such basic architectural change in contemporary cellular systems is very expensive to implement as it requires redesigning of several components and hardware; a major reason to delay the decoupling for later standards after a full feasibility investigation. A cellular SDN experimentation platform can, however, facilitates the performance evaluation and quick implementation of BCG2 architecture. It is high time to re-think the basic architecture of the cellular systems and not only make it energy efficient but also make them flexible and amenable for future growth. These two areas are getting huge interest of the research community and in our view their

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intersection also creates a unique space with immense potential of performance improvement. Our architecture is inline to phantom cell concept [4] which was introduced for realizing true potential of dense deployment of small cells as suggested for LTE Release 12. In this idea, many small cells, called the phantom cells as they contain only LTE user plane, are overlaid with a normal macro cell which provides interference coordination. However, a macro cell consumes over 100 times more power than a pico/femto cell as described in the EU FP7 EARTH project [2] and keeping it on all the time would lead to severe power inefficiency. In the proposed integrated architecture however, the signaling controller is used instead of the macro cell which is a low-rate signaling-only node consuming a small fraction of network energy. A signaling controller can also host a logically separated data node but it can be treated as any other data node in the area. Our simulation results show the exceptional potential of energy savings using our proposed architecture in comparison to phantom cell concept. The rest of the paper is organized as follows: in Section II, we review SDN and BCG2 themes and their salient features, the new integrated design is presented in Section III along with the important outstanding issues. Prominent advantages of the integrated architecture are presented in Section IV. Finally, Section V concludes the paper.

II. Background

A. BCG2 Architecture

The logical decoupling of data transmissions and control signaling paradigm is one of the key directions being explored by GreenTouch1 under the project Beyond Cellular Green Generation (BCG2) [1]. GreenTouch is a consortium of leading ICT industry and academic experts working towards 1000 times enhanced network energy efficiency compared to 2010 by delivering specific designs and recommendations by 2015. In BCG2 architecture, the signaling nodes are responsible for the coverage and are usually assumed to deliver low rate services, such as, random access and paging, over long ranges; whereas the data nodes can be activated and deactivated depending on the traffic demand and it is designed for high rate and small ranges. The decoupling is logical in nature and a single location can host both types of nodes. A preliminary study of BCG2 architecture is presented in [1], where it is shown, through statistical modeling, that energy efficiency of current systems can be improved by more than 50 times depending on the daily load profile. A set of studies regarding the BCG2 architecture is performed under the EU FP7 IP project EARTH [2]. The study shows that up to 85-90% saving potential is possible with this revolutionary changed architecture compared to the current systems. The results from these studies show the promise and potential of the BCG2 architecture. Although, considering the transition cost involved in moving to a new cellular architecture, a comprehensive feasibility study is necessary to clearly identify the cost-benefit trade-offs. Coverage is also separated from data processing in a Cloud RAN architecture [5], where a centralized BBU (Base Band Unit) pool serves several RRH (Radio Remote Heads) in the area and not-in-service BBUs can be put in sleep mode to save energy. The prohibitive aspects of Cloud RAN are the expensive fibre needed to connect RRHs to the BBU pool and the high bandwidth requirements for this fronthaul. Currently, the base stations consume over 80% of total network energy and are designed for high-data rate services. During low-traffic scenarios, such as, night time, they can only be put in sleep mode if there are redundant BSs covering the area, which is the usual case in dense urban environment. The decoupling will provide tremendous opportunity for improving energy consumption. Data nodes or the BSs responsible for data transmissions can employ more efficient energy management schemes with sleep modes and green radio technologies, such as optimized beam forming, in the BCG2 architecture compared to the contemporary systems. They are potentially the major power consumer. An incoming session should be allocated to an active data node which can provide the service, although it might not be the best BS for the job, as the incremental cost for serving an additional session is much smaller then activating a BS [1]. However, sending the transmission through a low SNR (Signal to Noise Ratio) path will affect the spectral efficiency of the system. Moreover, the channel between data BS and the mobile terminal cannot be estimated before selection as done in the classical approach. More sophisticated mechanisms are required to predict and estimate the channel condition between the mobile terminal and any potential data BS. Signaling nodes are responsible for providing coverage and always-on connectivity, paging the mobile terminals, and providing access to them when required [2]. They are supposed to be designed for low rate and long range transmissions and consuming low power.

B. Software Defined Radio Access Network

While the definitions of SDN are still evolving, it mainly focuses towards decoupling of the software-based control plane from the hardware-based data plane (e.g., packets forwarding) of networking and switching pieces of equipment [3]. The logically centralized controllers contain the control logic to translate the application requirements down to the data plane and are responsible in providing an abstract network view to the application plane. The major issue is to create appropriate mapping of the existing network functionalities to the decoupled control and forwarding planes. While a lot of the work is done for wired or optical networks, some proposals are also presented for cellular SDN architecture [3][6]. For the radio access part of the mobile communication system, two fundamental questions are as follows,

i. How to decouple the control plane from the base stations
ii. Where the control plane will be located?

The centralized controller in the state-of-the-art proposals of SD-RAN, either resides in the core network [6] or in a centralized data centre [3]. The design in [6] tries to push all the control plane functionality into a centralized controller in the core network and proposes the use of local switch agents for scalability. The proposition in [3] is focused towards refactoring the control plane into a virtualized big base station controller for a geographical area and local controllers within each base station for latency sensitive decision making. The

LTE architecture also distinguishes user plane, dealing with the data packet forwarding, and control plane, focusing on signaling and management messages and operations, using the same physical infrastructure. Both planes reside in the firmware of the system. This demarcation is much clearly designed in mobile core network EPC (Evolved Packet Core), but the radio access part of LTE consists of only base station node, eNodeB, performing data forwarding and control functions. The SDN based core network requires transporting the control plane into software along with the control logic required for the data forwarding plane, e.g., routing rules, mobility anchoring, etc. We also remark that user plane as defined by LTE is not exactly the same as data forwarding plane of SDN and similarly both control planes also differ slightly. In SDN, control plane relates to all control logic required to manage the network, connections, and forwarding the data packets. From SDN's perspective, base stations, serving gateway (S-GW), and packet gateway (P-GW) of LTE architecture are also performing some control plane functions along with data forwarding in addition to the designated control plane nodes MME (Mobility Management Entity), HSS (Home Subscriber Server), and PCRF (Policy Control and Charging Rules Function) [6]. Although not within the scope of SDN, but it is worthwhile to discuss an extreme approach of re-designing radio access architecture, i.e., the Cloud RAN [5]. Cloud RAN centralizes all functionalities, control as well as data plane, into a centralized BBU pool, or a data center, for easier management and coordination while leaving only antennas and some active RF components, i.e., RRH, on the cell sites. Cloud RAN is proposed as a mechanism to realize small cell deployment in LTE through proper coordination for interference management. LTE small cell, however, assumes distributed control with self-organizing (SON) capabilities. The backhaul from the cell site to the serving gateway (S-GW) could be through wired or wireless links (http://scf.io/). On the other hand, Cloud RAN assumes a high bandwidth fibre link between RRH and the centralized data centre, which is also the most prohibitively expensive aspect of this proposal. SoftRAN [3] observes that it is cost-effective to leave data plane functionality to the base stations along with some part of control plane for delay-sensitive decisions, but stressed on the coordination of closely-deployed BS in a dense network though a centralized virtual big base station. The idea of big BS or controller is very close to the signaling node in the BCG2 architecture and motivates us to explore the integration of both approaches. The authors of SoftRAN also presented a decomposition of protocols for data plane realization in cellular network in an earlier publication [7].

III. The Integrated Architecture

The evolution of contemporary LTE into the new integrated architecture is shown in Fig. 1. As depicted in [6], we also believe that the control plane of SDN based core network should contain some functional capabilities currently residing in S-GW (Serving Gateway) and P-GW (Packet Gateway), e.g., modification of routing rules, etc., along with the dedicated control nodes of EPC (Evolved Packet Core) shown with green dashed lines in Fig. 1. The functional decomposition of S-GW and P-GW is shown in Fig. 1 by means of control elements containing necessary APIs to EPC control nodes and also control logic required for data forwarding. These programmable control elements for routing modification etc., can be housed in control nodes in future architectures with specific APIs only in S-GW and P-GW. The interfaces between nodes in the core network, as shown in Fig. 1, are the same as EPC; but in a programmable SDN domain, they most probably be realized as software APIs. The data forwarding pipe is shown with a solid blue line passing through both gateways into the internet.

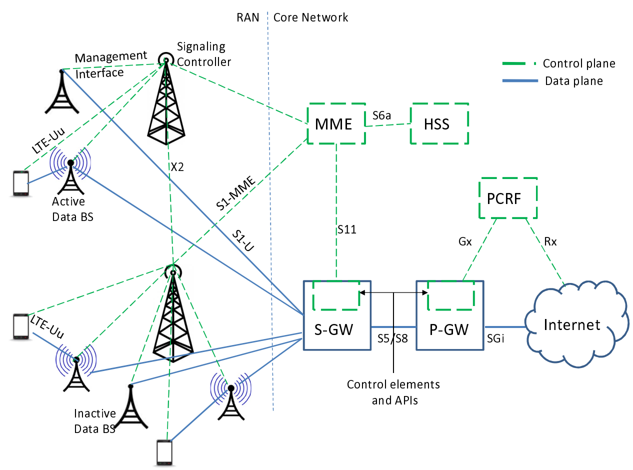

Fig. 1. The new integrated architecture

The new radio access system includes signaling controller, shown with big towers in Fig. 1, for a larger geographical area containing several data BSs shown with smaller towers in the figure. The eNodeB functionalities will be split between signaling controller and data BSs. The data BS can only be used on-demand and if there is no call, the data BS will be put in sleep mode as also shown in Fig. 1. The control plane interfaces are shown with green dashed lines and the data paths are shown with blue solid lines in Fig. 1. We propose that only signaling controller requires to have an interface with MME (Mobility Management Entity), performing similar functions as S1-MME of EPC. The data BS requires connections to S-GW for data forwarding with the interface similar to S1-U of EPC. Moreover, when mobile user is crossing the signaling controller coverage boundaries, a coordinated handover can be realized through communication between two signaling controllers. The interface between two signaling controller is labeled as X2 in Fig. 1, as it requires almost similar specifications as the interface X2 between eNodeBs in LTE but excluding functions related to data transmission and tunneling. Within the coverage area of a signaling controller, the handoff between data BS will be managed by the single associated signaling controller, most probably as part of the resource management function. The UE (User Equipment), also requires interfaces to both signaling controller for system access and data BS for data transmissions. The interfaces are similar to

LTE-Uu interface which is defined to both control and data traffic in LTE. The only new interface in our architecture is the connection between signaling controller and the data BS, denoted as management interface in Fig. 1. This interface is similar to X3 interface in phantom cell concept [4] though implemented through software APIs. The management interface will be used for resource allocation by signaling controller and periodic updates from data BS for interference management. This connection can also be realized through dedicated wireless links or by any other wired technology if available.

A. Singalling Controller

The major component of our new integrated architecture is the signaling controller which performs the functions of a signaling node in BCG2 architecture and also of the centralized controller for SDN based radio access network. The combined specifications for the signaling controller conforming to the SDN principles and BCG2 architecture are given in Table I. Since control plane implementation will be done using general purpose processors, the power consumption of a signaling node is not expected to substantially increase because of additional controller functionalities.

TABLE I. COMBINED REQUIREMENTS FOR SIGNALING CONTROLLER

SDN	
1	hosts control logic for RAN, i.e., interference management, resource management, coordinated handover, etc.
2	programmable on general purpose processors
3	provides APIs to BSs and also to core network
BCG2	
1	provides signaling for system access and paging
2	has interfaces to UE, data BSs, and core network
3	performs resource allocation
4	consumes less power

1) Resource Management and Assignment: In the BCG2 architecture, the possibility of sub-optimal channel allocation is one of the major concerns [2], for two reasons: 1) the channel between data BS and the mobile terminal cannot be estimated before selection as done in the classical approach and more sophisticated mechanisms are required to predict and estimate the channel condition between the mobile terminal and any potential data BS, such as, location of the user, etc. 2) It is less costly to allocate an in-coming request to an already active BS rather than waking up an inactive one; although it might not have the best possible channel to the user. However, the signaling controller can, not only null the ill effects described above but can actually optimize system capacity and energy efficiency trade-off with efficient resource management and interference mitigation using periodic updates from data BSs under its coverage and re-allocation of resources if it improves the capacity/energy trade-off. In order to predict channel between user and inactive BS, phantom cell concept proposes to save SNR (Signal-to-Noise Ratio) map with each phantom cell [11]. In addition to the requirement of an initial training phase and excessive memory requirements, this method assumes constant transmission power and over-averaging of SNR values from UE which in fact can only measure SINR (Signal to Interference and Noise Ratio) instead. We evaluated the performance of two methods of BS selection, i.e., 1- with best signal strength and 2- with minimum distance to the user, using real drive-test data from cellular networks in urban and suburban scenarios. We collected around 1000 observations with GPS location and signal strengths of nearby BSs. Although, the BSs were not small BSs but the data still provides insight into the performance of both methods. We remark that in dense deployments, it suffices if we select a BS among the top n best BSs by any possible method. We calculated mean signal strength over a moving window of 100 observations to find the most consistent or best BS. The results in terms of probability of missed detection are given in Fig. 2. We plotted the probability against the acceptable number of best BSs. i.e., $n = 1, .., 5$. The results in Fig. 2 shows that both method are good and comparable for suburban settings, although, for urban scenario, both has large errors specially minimum distance selection has unacceptable performance. With smaller distances between users and BSs in dense deployments and lesser chances of obstacles in between, minimum distance discovery is expected to perform better than the performance shown in Fig. 2. BS discovery while in sleep mode is still an open problem and an important part of our on-going work.

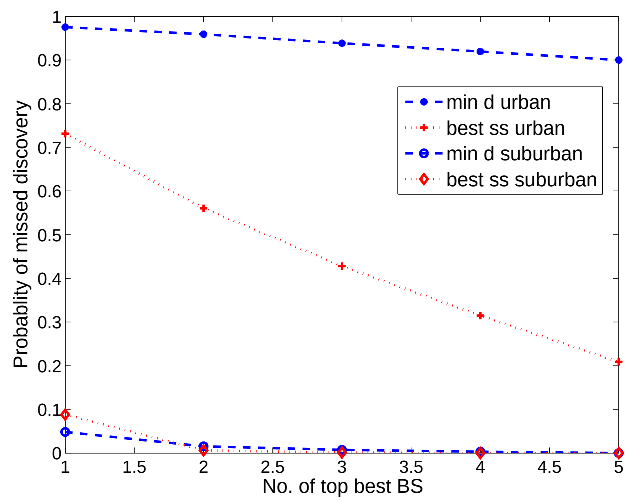

Fig. 2. Probability of missed discovery of best BS with minimum distance (d) and best signal strength (ss) methods for urban and suburban scenarios.

Resource management is a multi-objective optimization problem which maximizes capacity $r_i(\eta) = \log(1 + SINR(\eta))$, where $SINR(\eta)$ is signal to interference and noise ratio, and minimizes power consumption $p_i(\eta)$ for all i users. If transmission power is kept constant, the $SINR(\eta)$ would depend on the specific resource block allocation to closely spaced users. Based on the above definitions, the optimization function can be defined as follows,

$$\min_{\eta} ECI(\eta) = \min_{\eta} \left\{ \frac{\sum_i p_i(\eta)}{\sum_i r_i(\eta)} \right\} \qquad (1)$$

where $ECI(\eta)$ is the commonly used energy consumption

index with units of W/bps or J/bit [2] and is the parameter vector. The parameter space is a 3D resource grid containing the resource blocks, i.e., frequency carrier and time slot and data BSs. Under the new structure, the resource block mapping to the data BS does not need to be static and may be calculated by the resource management entity. Exploiting the ideas developed under self-organizing networks, the resource management parameter space can be extended to include BS variables, such as, transmission power, antenna tilt, etc. A very simplified case study is presented in Fig. 3 to explain our idea of optimal resource management or re-allocation. Here one data BS is assigned 2 voice calls (64Kbps each) and 1 video streaming session (384Kbps). The streaming video session requires approximately 6 times more resource blocks than the voice calls. The relative distances of each user are also given with the serving data BS for both scenarios in Fig. 3. If we ignore all other effects and assume that transmit power for each resource block should compensate the respective path loss $L \propto d^{\gamma}$ (urban path loss exponent γ is 8), the required total transmit power needed for all resource blocks in scenario 1 will be approximately $4.5 \cdot 10^3$ times more than the power consumption for scenario 2 for the same required data rate and it saves a lot of energy if the systems moves from scenario 1 to
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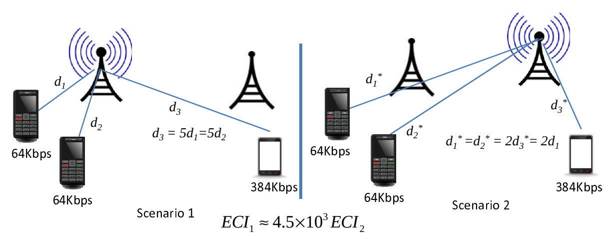

Fig. 3. An example of optimal resource management.

2) Mobility Management: There are also some important implications in terms of managing mobility which implicitly also relate to energy consumption. The two salient features of IP based mobility management protocols, such as, fast handovers for MIPv6 [8], hierarchical MIPv6, and proxy MIPv6, are: 1- they are centralized and based on a mobility anchor located within the network domain and 2- these mobility protocols do not separate control and data planes. The former issue propelled discussions towards the Distributed Mobility Management (DMM) [9] solutions where the anchoring is done at the Access Point (AP) or BS; hence these functionalities are distributed at the points of attachment of the mobile nodes. Decentralization would alleviate network bottlenecks enabling better routing decisions at the same time. Nevertheless, clear benefits of such decentralization would emerge especially for the cases where the session duration time is significantly less than the cell residence time. The performance for high mobility users and/or delay sensitive flows under a DMM framework is very much topology dependant since the flows have to be tunneled form the old AP to the new AP under DMM. Regarding the second salient feature, in order to be compliant with an SDN-like separation of data and control planes and in the case of DMM, the APs will act as forwarding plane anchors and mobility related control functionalities will be logically centralized. In the proposed architecture these planes are physically decoupled, as shown in Fig. 4, and therefore localized mobility control will be required to take place via the signaling controller node. The signaling controller node will acquire all the control functionalities of a Mobile Access Gateway (MAG) and with control exchanges with the Local Mobility Anchor (LMA) will encapsulate the IPv6 address of allocated data BS for the mobile node. As shown in Fig. 4, the signaling node will act as an MAG for the mobile node which in essence means it has to provide a proxy Care of Address (pCoA) from the pool of available resources of the data BS in which the UE will be connected to (both in the case of new calls and handover calls).

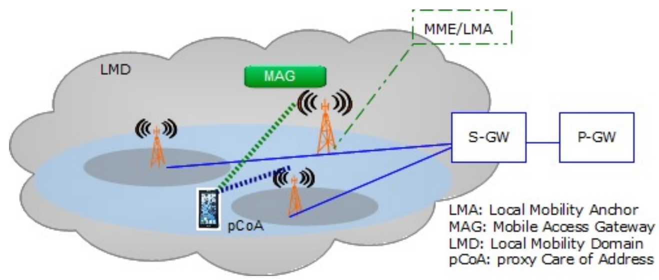

Fig. 4. Mobility management in the new architecture.

B. Data Base Stations

Data BS belongs to the data forwarding plane. Under the new structure, they require to perform baseband processing and other transmission tasks as defined by the control plane. They will only be used on-demand as they are the most energy consuming component of the system. If not in use, they should be put in sleep mode to save energy. The cost of activation and de-activation should also be considered along with the activation delay while assessing the costs and benefits of the new architecture.

IV. Advantages of the Proposed Architecture

A. Energy Efficiency

The major objective of phantom cell concept is to provide interference coordination to dense deployments of small cells through a macro cell. Although, as the macro cell also takes care of the coverage, the small or phantom cell can be put in sleep mode if not in use. A macro cell consumes over 100 times more power than a pico/small cell as estimated in EU FP7 EARTH project [2] reducing the energy efficiency of phantom cell architecture. In Fig. 5, we show the mean daily consumption of phantom cell and our proposed architecture and compare it with the baseline scenario of all active nodes. It is clear that the reduction in phantom cell consumption only becomes prominent in very dense settings, whereas, our proposed architecture based on the decoupling of signaling and data improves energy efficiency greatly. The simple simulation scenario consists of 1 macro cell and a number of homogeneous small cells. In our architecture, the macro BS is a signaling controller which consumes negligible energy [1]. We assumed uniformly distributed small BS and UEs in the macro cell radial range of 2km. The total number of UEs in peak hour are assumed to be 10 times the number of BSs and proportional number of UEs are calculated for each 2 hour slot of the day using daily traffic profile introduced by EARTH [1-2]. Each UE connects to the BS with lowest path-loss, i.e., minimum distance. The BSs are assumed to have sufficient capacity to serve the allocated UEs. The nodes without any associated user are assumed to be in sleep mode with zero energy consumption. A better resource allocation algorithm can be designed for both architectures to optimize the capacity/energy trade-off which should benefit both in the similar manner. Moreover, sleep mode also consumes small amount of energy [2] but it is ignored in this evaluation. The small cell BS consumption is normalized to 1 watt.

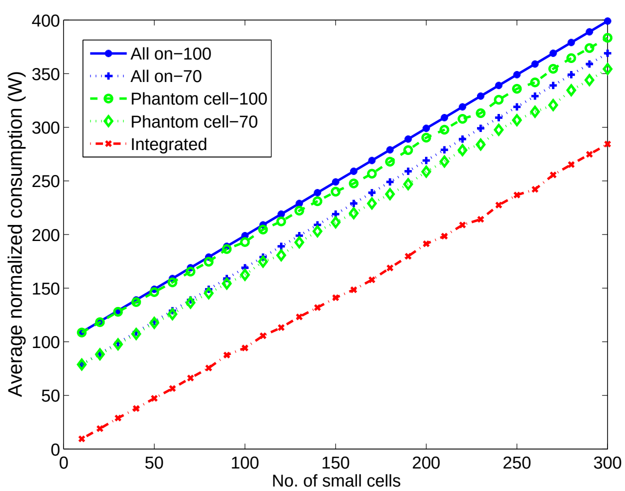

Fig. 5. Energy efficiency of the proposed architecture in comparison with all-nodes-on scenario and phantom cell concept.

The average daily energy consumption of phantom cell and our architecture is shown in Fig. 5, where it is clear that the consumption of always-on macro cell in phantom cell concept offsets the energy savings of small cells in sleep mode. We also tried to estimate the average daily consumption when macro cell consumes 70% more power than small cells. The results are labeled as All on-70 and Phantom cell-70, whereas the results when macro cell's consumption was 100 times more, as described in [2], are labeled as All on-100 and Phantom cell-100. In both scenarios, phantom cells become really beneficial in very dense deployments of small cells. In our on-going work, we are estimating the energy requirements of a signaling-controller for clear identification of the margin of benefit. In Fig. 5, our proposed architecture is slightly favored as the consumption of signaling controller is ignored, however, it will be much smaller than the consumption of a normal macro cell, still making our architecture the most energy efficient architecture for 5G which also comes with unprecedented ability of interference management to realize true benefits of dense deployments.

B. Virtualization and RAN sharing

Network function virtualization is one of the prime benefits of SDN where various virtual networks can use the same physical infrastructure. For example, the signaling controller can be shared by various operators. Each can control its radio resources with or without collaboration with other operators. RAN sharing has also been proposed and practiced in 3GPP systems. The most comprehensive framework is developed by NEC [10], which is based on minimum guaranteed reservation of resources for each operator. In our on-going work, we are developing the idea of opportunistic RAN sharing with our proposed architecture. Opportunistic RAN sharing is a novel idea where infrastructure and radio resources are opportunistically shared among operators only if it improves the capacity/energy efficiency trade-off which can then be mapped into proportional gains for sharing operators. Since all access requests will be coming to the signaling controller, it is much easier to design radio resource sharing algorithm with optimal performance over a finer time scale. As an example, we consider night scenario where around 15% of the traffic is expected compared to the peak load [1]. Two operators in an area, each individually serving 15% of its subscribed users, can provide service to all the clients with better utilization of the BSs and resource blocks providing better capacity/energy trade-off. The gains can be shared among the operators in proportion to their costs.

C. Enabling Technologies

BCG2 architecture proposes a basic structural change in contemporary mobile communication system which requires re-designing of several components, such as, mobility management, resource allocation, etc., affecting the whole system which is the main reason to delay its implementation till the future standards. To this end, an SDN programmable control plane could be the enabling technology to realize cell on-demand architecture by facilitating development and implementation of appropriate modifications in the protocols. On the other hand, signaling node as defined by the BCG2 architecture could be the best location to host the control plane for a particular scope coverage geographical area of a radio access network. The integration of SD-RAN and BCG2 architecture enables an energy efficient mobile communication system to reach near-optimal capacity in a co-channel interference environment. In addition to the above benefits, the proposed architecture provides clear demarcation of control and data plane specially in the radio access part enabling the realization of various novel aspects of SDN, such as for example network virtualization and network function virtualization.

V. Conclusions

We present an integrated approach combining SDN based RAN and BCG2 architecture, by means of a signaling controller which provides always-on system access and contains control plane functionalities. The major takeaway message of this article is that both visions carry more potential than the benefits they are aiming for; and a union of both sets of requirements and specifications will result in an even richer and more commercially viable design of mobile communication systems. The proposed architecture is also very close to the phantom cell concept, although, our architecture has the potential to reduce energy consumption over multiple order of magnitude in comparison to phantom cells. Future avenues of research include a detailed functional view of the architecture where various components such as mobility and topology control can be envisioned within a Network Function Virtualization (NVF) paradigm in a cloud empowered RAN.

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