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1 WG to which this Contribution is submitted (see http://www.wwrf.ch/workinggroups.html for working group descriptions):

- ☐ **Working Group A: User Needs & Requirements in a Wireless World**
- ☐ **Working Group B: Services, Devices and Service Architectures**
- x **Working Group C: Communication Architectures and Technologies**
- ☐ **Working Group D: Radio Communication Technologies**

2 Title of the contribution

An integrated approach for future RAN architecture

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4 Keywords

Radio access network architecture, Software defined networking, decoupled signaling and data, Phantom cell concept, energy efficiency

5 Extended Abstract

Background and 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.

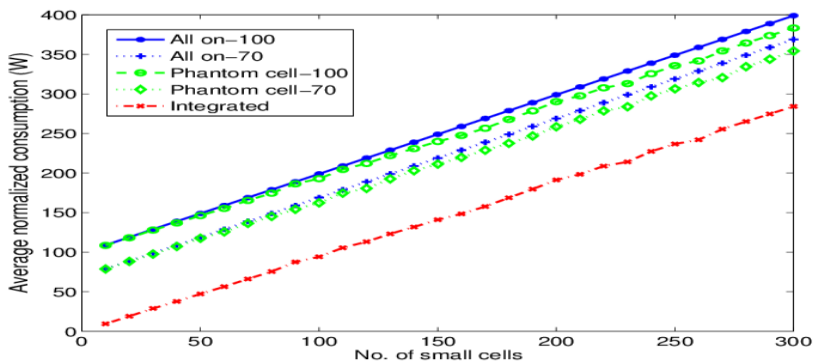

Fig.1Energy efficiency of proposed architecture, Phantom cells and all-nodes-on scenario when macro cell consumes 100 and 70 times more energy then small/pico cells.

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. In Fig.1, 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 uniformly distributed small cells. In our architecture, the macro BS is a signaling controller which consumes negligible energy [1].

Major Advantages: Along with exceptional energy efficiency potential as discussed above, 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 practised in 3GPP systems. 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.

Major Issues: In order to predict channel between user and inactive BS, phantom cell concept proposes to save SNR map with each phantom cell. 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 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 a cellular networks in urban and suburban scenarios. The data consists of almost 1000 observations with GPS location and pilot signal strengths of nearby BSs in downtown and suburban areas of a major US city. 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 show 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. BS discovery while in sleep mode is still an open problem and an important part of our on-going work.

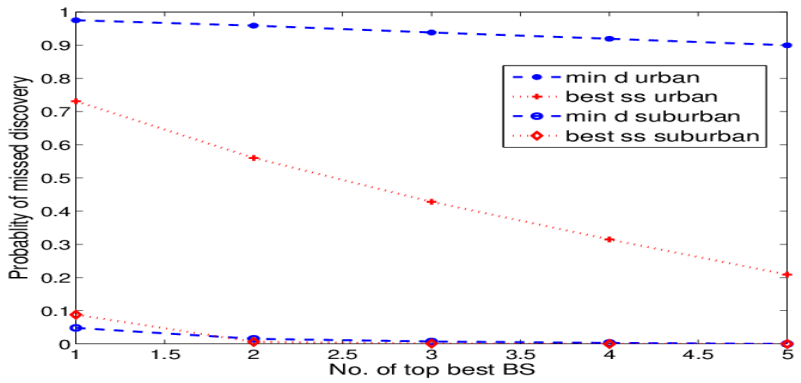

Fig.2 Probability of missed discovery of best BS with minimum distance (d) and best signal strength (ss) methods for urban and suburban scenarios.

References: [1] Capone, A. et al., "Rethinking cellular system architecture for breaking current energy efficiency limits," SustainIT 2012 , vol., no., pp.1,5, 4-5 Oct. 2012

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