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A Cluster Based Approach for Maximizing the Energy Efficiency of Wireless Small Cell Network

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ABSTRACT:
The exponentially increasing demand for wireless data services requires a massive network densification that is neither economically nor ecologically viable with the current cellular system architectures. A promising solution to this problem is the concept of small-cell networks (SCNs). In SCNs t is necessary to have self-organizing, low-cost, low-power, base stations (BSs). Although SCNs have the potential to significantly increase the capacity of cellular networks while reducing their energy consumption, they pose many new challenges to the optimal system design. SCNs, performing dynamic approaches for switching BSs ON and OFF may require the knowledge of the entire network to operate effectively which incurs significant overhead. We proposed a novel cluster-based approach for maximizing the energy efficiency of wireless SCNs. A dynamic mechanism is proposed to locally group coupled small cell base stations (SBSs) into clusters based on location and traffic load. Within each formed cluster, SBSs coordinate their transmission parameters to minimize a cost function, which captures the tradeoffs between energy efficiency and flow level performance, while satisfying their users' quality-of-service requirements. A distributed learning algorithm is proposed using which clusters autonomously choose their optimal transmission strategies based on local information.

INTRODUCTION:
Recent advances in wireless communications and micro-electro-mechanical systems have motivated the development of extremely small, low-cost nodes that possess signal processing and wireless communication capabilities. Small Cell Networks (SCNs) deliver cost-effective capacity and coverage, indoors and outdoors. It plays a pivotal role in bringing huge amount of data capacity, where it is needed the most, by bringing the network closer to the users. The number of mobile phone subscribers worldwide increased from 700 million to 5 billion during the period 2000 to 2010 with the fastest growth occurring in developing regions including China and India [1]. Data volumes in wireless networks are predicted to grow significantly, yielding higher energy budgets and costs. Techniques to reduce the energy consumption of base stations in future networks is therefore of primary interest. Small access points (SAPs) such as femtocells, and picocells are commonly seen as a solution to meet this growing data demand. It is expected that over 70 million femtocells will be deployed by 2016 [3].

Hence to rapidly achieve hyper-densification, it is important to adopt a more 'unplanned 'ad-hoc deployment approach, where-in, there is no need for detailed RF network planning and optimization. The small cells have to be plug-and-play and self-configurable. These small cells could be operator or user installed, but managed by operators, and coordinate with macros as well as other small cells. As data traffic rises and the risk of congestion grows, supplementing macro networks with small cells is an effective way to provide capacity for indoors and outdoors, as well as for enterprises. Yet it can be challenging to deal with the higher control traffic, interference between the macro and small cell networks and backhaul bottlenecks.

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In [2], an optimal deployment strategy is proposed for a two-tier network based on power minimization subject to a target spectral efficiency. The results [2] suggest that the deployment of pico cells along with a traditional cellular network can improve the energy efficiency of the network, as well as provide gains in terms of increased inter site distance. The work in [3] introduces a stochastic programming approach to minimize energy consumption by optimizing small cell base station (SBS) locations. It investigates techniques to optimize the number of base stations and their locations, in order to minimize energy consumption. In [4], a greedy algorithm for turning base stations (BSs) on or off is proposed to improve the tradeoff between energy efficiency and traffic delay. Here, they specifically, formulate a total cost minimization that allows for a flexible tradeoff between flow-level performance and energy consumption. For the user association problem, an optimal energy-efficient user association policy is proposed and further present a distributed implementation with provable convergence.

A probabilistic sleep-wake mechanism is presented in [7] to optimize energy efficiency of relays in conventional cellular networks. Here the joint optimization of relay station (RS) placement and RS sleep/active probability is considered in order to enhance the energy efficiency of a one-dimensional cellular network. When the RSs are always active, they derive the conditions for optimal RS placement that minimizes transmission power of base stations (BSs) and RSs, subject to a user rate requirement. A random ON/OFF strategy for data networks is proposed in [9] for energy reduction by analyzing the distributions of delay tolerant and intolerant users. Data applications can tolerate an initial delay before packet transmission begins. It is possible to take advantage of this initial delay to reduce the energy required to operate the small access points (SAPs) and decrease transmission power in small cell networks. In [17], a clustering-based resource allocation and interference management scheme is proposed for femtocells based on exhaustive search.

Here Small cells such as femtocells overlay on the macrocells enhance the coverage and capacity of cellular wireless networks and increase the spectrum efficiency by reusing the frequency spectrum assigned to the macrocells in a universal frequency reuse fashion. The authors in [18] introduce an inter-cluster interference coordination technique to improve the sum rate of a femtocell network. In this paper, they design a hierarchical, distributed, interference management scheme that exploits the benefits of clustering. In [19], a threshold based BS sleep algorithm is proposed to improve the energy efficiency of cellular networks by using a Delaunay triangulation graph. Here they study the base station (BS) turning-off operation that can run without knowing the global knowledge of dynamic traffic distribution in time and space. They propose a green self-organizing network (SON) framework based on an overlay network using Delaunay triangulation (DT). Specifically, they propose a threshold-based BS off algorithm for reliable and operator-friendly operation.

TYPES OF SMALL CELL NETWORKS

Small cells may encompass femtocells, picocells, and microcells. Small-cell networks can also be realized by means of distributed radio technology using centralized baseband units and remote radio heads. Beamforming technology (focusing a radio signal on a very specific area) can further enhance or focus small cell coverage. Small cells provide a small radio footprint, which can range from 10 meters within urban and in-building locations to 2 km for a rural location.

Small cells, which have a smaller coverage area than base stations, are categorized as follows:

- Microcell, less than 2 kilometers
- Picocell, less than 200 meters
- Femtocell, around 10 meters

ADVANTAGES OF WIRELESS SCN's

- Easily scalable solutions to meet changing capacity needs.

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- Services ensure the right investments for the right network.
- Get the best solutions for both public indoor and enterprise use.
- Small-cell can be deployed open access and closed access/restricted.
- In home use can support up 4-6 mobile users and for business use can support up to 16-20 users, (dependent on small-cell coverage).
- Small-cell connect with the main networks using digital subscribers line (DSL) or cable broadband (wired or wireless front haul options).

Use of SCN benefits both the mobile operator and the consumer.

- For a mobile operator, the attractions of a femtocell are improvements to both coverage, especially indoors, and capacity. Coverage is improved because femtocells can fill in the gaps and eliminate loss of signal through buildings. Capacity is improved by a reduction in the number of phones attempting to use the main network cells and by off-loading the traffic through the user's network (via the internet) to the operator's infrastructure.
- Consumers and small businesses benefit from greatly improved coverage and signal strength since they have a de-facto base station inside their premises. As a result of being relatively close to the femtocell, the mobile phone (user equipment) expends significantly less power for communication with it, thus increasing battery life. They may also get better voice quality via (HD voice) depending on a number of factors such as operator/network support, customer contract/price plan, phone and operating system support. Some carriers may also offer more attractive tariffs, for example discounted calls from home.

EXISTING SYSTEM

Cellular traffic has rapid stochastic variations over hours and days. Therefore, increasing number of cells with small coverage and with no active user will waste power. As the number of BSs increases, a UE must exchange control signals with more BSs. Hence unnecessary signaling load not only drains the battery of UEs but also increases interference in a network Therefore, dynamic ON/OFF schemes is needed to reduce the number of unnecessary SBSs surrounding a UE. In an optimal deployment strategy [2] power minimization is subjected to a target spectral efficiency. In a random ON/OFF strategy [9] the data networks is affected by energy reduction of delay tolerant and intolerant users. In addition, some of practical problems of small cells such as the selfish behavior of BSs, the inefficient BS switching between ON and OFF, the underutilized radio spectrum as well as potential undesirable outages at BSs are not taken into account [8], [9], [11].

PROBLEM STATEMENT

In small cell networks, performing dynamic approaches for switching BSs ON and OFF may require the knowledge of the entire network to operate effectively which incurs significant overhead. Due to the lack of inter-cluster communications, clusters compete with one another to improve the overall network's energy efficiency. This inter-cluster competition increases overhead among clusters.

SOLUTION METHODOLOGY

Novel cluster-based approach for maximizing the energy efficiency of wireless small cell networks is proposed. A dynamic mechanism is proposed to locally group coupled small cell base stations (SBSs) into clusters based on location and traffic load. Within each formed cluster, SBSs coordinate their transmission parameters to minimize a cost function, which captures the tradeoffs between energy efficiency and flow level performance, while satisfying their users' quality-of-service requirements. Due to the lack of inter-cluster communications, clusters compete with one another to improve the overall network's energy efficiency.

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A distributed learning algorithm is proposed using which clusters autonomously choose their optimal transmission strategies based on local information.

SYSTEM ARCHITECTURE

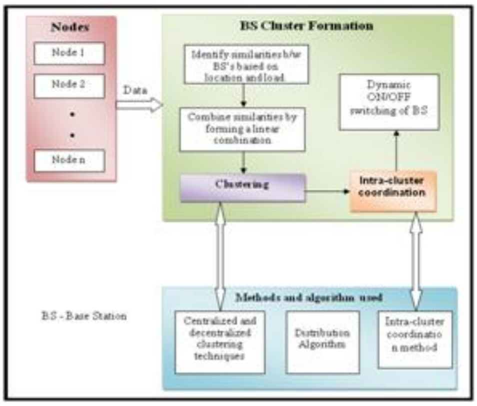

Figure 1: System Architecture

The system is made up of a number of mobile nodes which are served by the small base stations. BS are grouped together to form a cluster. Clusters are formed based on the similarity between BS's load and the distance. Once the similarity is identified the similarities are combined by forming a linear combination to form a clusters. The two types of clusters are formed called inter-cluster and intra-cluster formation. A dynamic ON/OFF switching of BS is performed based on traffic and distance information. A distributed learning algorithm is proposed using which clusters autonomously choose their optimal transmission strategies based on local information.

Level 0 DFD

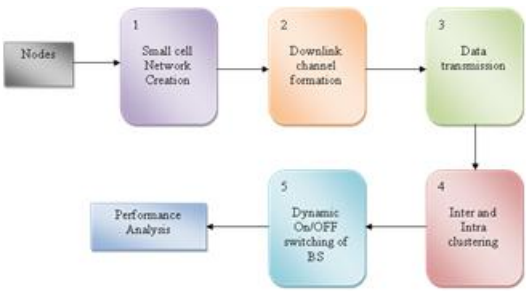

Figure 2: Level 0 DFD

The above figure shows the level 0 DFD, it contains six top level models. The proposed framework signifies the implementation of Dynamic Clustering and ON/OFF mechanism that ensures to minimize the energy consumption among nodes in the network. In small cell network creation module the SCN is initialized and setup nodes are randomly deployed. In downlink channel formation SBS broadcast control messages to all nodes in network. Collects the list of all the neighboring nodes and forwards it to the SBS's. After obtaining the list the base station node can form clusters. In data transmission module the data is sent from the UE to the Main Base Stations via Small Base Stations. In cluster formation similarities are identified between BS's based on location and load.

Combine similarities by forming a linear combination. Once clusters are formed the lightly loaded BS within the cluster is selected as the cluster heads. The function of a cluster head is to coordinate the transmissions between the cluster members. Develop a self-organizing mechanism, in which each cluster of BSs adjusts its transmission parameters based on local information. To do so, we use a regret-based learning approach. In the proposed approach, clusters need to autonomously select their transmission configurations to minimize their cost functions. Performance of Proposed Mechanisms Based on Network Cost & Reductions of Energy Consumption and Time Load.

RESULTS AND ANALYSIS

NS-2 simulator is used to evaluate the performance of the proposed protocol. A wireless small cell network is simulated. The traffic is generated at constant speed, with a packet size of 512 bytes, transmission rate is 180 kbps. Source sends a packet to destination at an interval of 0.1 seconds.
The following table gives the simulation parameter for the nodes.

Table 1: Simulation Parameter

Parameter	Value
Carrier Frequency	2GHz
System bandwidth	10MHz
Mean traffic influx rate	180kbps
Max. Transmission Power MBS, SBS	46, 30 dBm
Minimum distances between MBS, SBS and Mobile node	
MBS-SBS, MBS-Mobile Node	75m, 35m
SBS-SBS, SBS-Mobile Node	40m, 10m
Clustering	
Range of neighborhood	250m
Tradeoff between similarities	0.5

SIMULATION RESULTS:

For our simulations, we consider a single macrocell under-laid with an arbitrary number of SBSs and mobile nodes uniformly distributed over the area. We conduct multiple simulations for various practical configurations and the presented results are averaged a large number of independent runs. The parameters used for the simulations are summarized in Table 1. The proposed cluster-based coordination mechanism is compared with the conventional network operation referred to as "classical approach" in which BSs always transmit. Figure 1 shows the average cost per BS verses the Range of neighborhood. Here the red line indicates classical approach and the green indicates the proposed approach. It can be seen that as the range of neighborhood increases the average cost per BS increases gradually in proposed approach whereas in classical approach the cost per BS decreases as the range of neighborhood increases. Hence the proposed approach is efficient when compared with the classical approach.

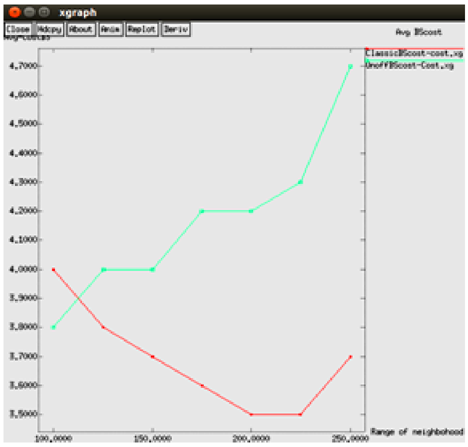

Figure3: Average cost verses Range of neighborhood

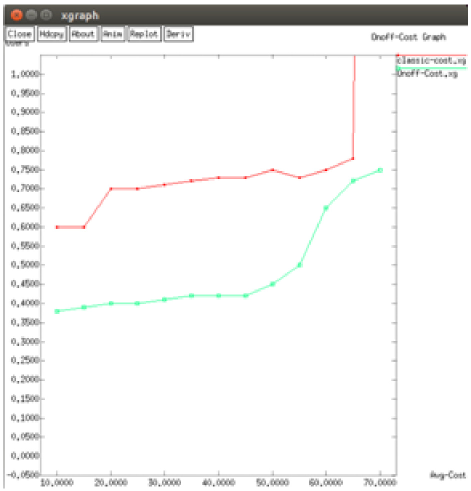

Figure 4: Number of users verses Average Cost

Figure 4 shows the number of user's verses average costs curves. The cost of the BS is more in classical approach where as the proposed algorithm is efficient.

CONCLUSION AND FUTURE WORK

We have proposed a novel cluster-based energy efficient mechanism for small cell base stations. Clustering allows clustered base stations to coordinate their transmission while the clusters compete with one another to reduce a per-cluster cost based on their energy consumption and time load due to their traffic. We have proposed a distributed algorithm and an intra-cluster coordination method using which base stations choose their transmission mode swith minimum overhead. Our proposed clustering methods uses information on both the locations of BSs and their capability of handling the traffic and dynamically form the clusters in order to improve the overall performance. For clustering, both centralized and decentralized clustering techniques are introduced and the performances are compared. Simulation results have shown significant gains in energy expenditure and load reduction compared to the conventional transmission techniques. Moreover, the results provide an insight of when and how to reap the benefits from the cluster-based coordination in small cell networks.

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