Performance Evaluation of Mobile Stations using Low Power Node in Macrocell Network

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***Abstract*-The tremendous growth in demand for higher data rates and other services in mobile communication technology have increased the number of worldwide cellular base station. Whereas conventional macro-cellular network deployments are less efficient, it may not be economically feasible to modify the current network architectures. One obvious way to make the mobile network more power efficient to sustain high speed data-traffic is by decreasing the propagation distance between nodes, reducing the transmission power. Thus in the proposed work low power nodes or heterogeneous small cells are introduced between the macro-cells and the mobile stations in order to achieve the required power efficiency. Also an intensive analysis is done on the performance metrics of the mobile stations, such as throughput, end to end delay and jitter, comparing their behavior in the conventional and proposed architecture.**

Keywords- Macro-cellular network; Power Efficiency; Propagation distance; Low power nodes; Performance metrics;

I. INTRODUCTION

The emerging trend of achieving energy efficiency in cellular networks acquires concern from cellular operators to not only maintain effectiveness, but also to reduce the overall environment effects encouraging the standardization authorities and to continuously explore future technologies in order to bring improvements in the entire network infrastructure. Heterogeneous network deployment based on smaller cells is a technique that can possibly reduce the power consumption of a cellular network. Conversely, some of the recent research suggests, cautious network design is required as deploying too many smaller cells may in fact reduce the power efficiency of the central base station (BS). Also, when a large number of BSs with small cell are deployed, the embodied energy consumption will dominate and lead to an increase in total energy consumption. It has been reported that compared to macro-cell

A standard shift in cellular network infrastructure deployment presents many opportunities for capacity enhancement and many new disputes in co-existence and network management. This occurs away from traditional (expensive) high power tower mounted base stations and towards heterogeneous elements.

A very significant improvement is the use of heterogeneous base stations under laid in a traditional macro cellular network. There are different classes of low power nodes (LPNs) in such a heterogeneous network that are distributed throughout the macro cell network [2].

The various types of LPN are including micro base stations (eNodeBs or eNBs), pico eNBs, home eNBs (also called femto cells), relays and distributed antenna systems (DAS, also called remote radio heads or RRHs). In heterogeneous network (HetNet) deployments, the overlay macro cell provides a wide area coverage umbrella while the LPNs are deployed in a more targeted manner to alleviate coverage dead zones, and more importantly, traffic hot zones.

In comparison with macro BS, low power BS requires lower transmission power, smaller physical size and less expensive. Installing low power BSs in the coverage of macro BSs is considered to be an economical way of meeting the sharp increase of wireless applications, leading to a new model of network plan for the future generation networks.The problem of cell planning in such heterogeneous networks with minimal cost is the planning task, how to select the subset of possible BS sites, including macro BSs, pico Bs and relay nodes such that the satisfying all rate requirements of demand nodes [3]. The total power consumption of an LPN is typically small (10 - 25 W), there are hundreds of millions of

This is a different approach from the conventional statement of using mobiles in the locality as relay stations, to using fixed relay stations instead [7]. This also provides an entry mechanism by creating groups, based on the mobile stations (MS) accessing the base station via relay station (RS) and MS accessing the BS directly multi-hop relay networks to improvise the range of the existent cells and analyze the power saving obtained, but still not any of the above have adopted the problem of highly mobile environments, such as those experienced while moving in high speed trains, and analyzed.

II. NETWORK DEPLOYMENT

Macro cells are generally designed to provide large coverage but are not efficient in providing high data rates. Due to the fast increasing demand for mobile communication technology the number of worldwide cellular BSs has increased from a few hundred thousand to many millions within the last couple of years. This large shoot in the number of base stations will lead to an emission of green house gases and result in the pollution of the surroundings. Also installing such a great number of BSs will result in high expense. Therefore, cellular network deployment based on low power nodes is introduced. This appears to be a promising solution.

These small cells have the capability of improving spatial reuse and coverage by allowing forthcoming cellular systems to attain higher data rates, while retaining flawless connectivity and mobility. Improving energy efficiency also helps network operators reduce the operational cost as energy constitutes an important part of their disbursement. Accordingly, the terminology of "green cellular network" has become very popular recently, showing the current attitude of the telecom industries to place more importance on energy efficiency in of the role of a key performance indicator for cellular network design.

Another great problem for the future networks from the existing networks and technology development is power optimization. Improving network performance and enhancing the features in the mobile station with minimal usage remains a big challenge. The multi-hop relay networks manage the range of the existent cells and analyze the power saving obtained, but still none of the above have taken up the issue of highly mobile environments, such as those experienced while moving in high speed trains, and analyzed the networks accordingly. Fig 1. shows the heterogeneous small cell network of three-tier structure containing a marcocell base station, pico cell and Relay station

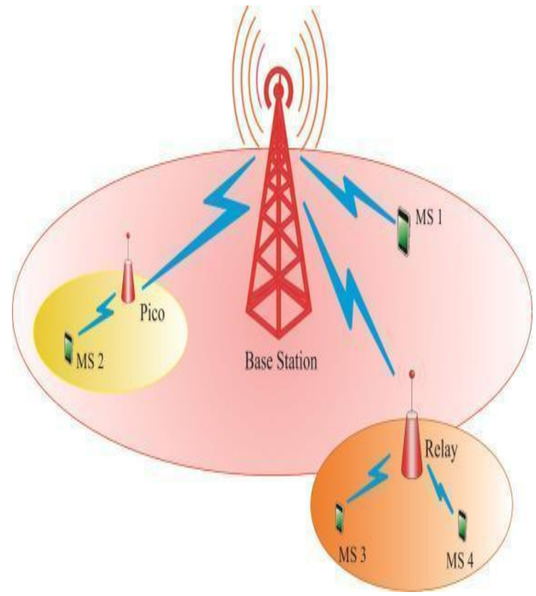

Fig .1. A typical heterogeneous small cell network

The backhaul link between a macro BS and its relay is wireless, so no landline is required. In comparison with a macro BS, the price of a low-power BS, including installation and maintenance operation is much cheaper. Also due to its lower transmission power and smaller physical size, low-power BSs can offer flexible site acquisitions.

Relay networks have small form factor and low cost relays linked with Base stations. There are three main benefits of relay based architecture over conventional architecture namely,

- Throughput Enhancement - increases system capacity by deploying RSs in a manner that enables more aggressive spatial reuse.
- Coverage Enhancement/Extension – improves the coverage reliability in areas that are out of the reach from the BS and extend its range.
- Cost Reduction – Using RSs, an operator with wide coverage delivers cost gains over traditional architecture.

- *System Model*

The design in Qualnet 5.0.2 network simulator, the network topologies are created with Qualnet architect. Two scenarios are illustrated here. In the current scenario, a macro cell base station is directly connected to the mobile stations.

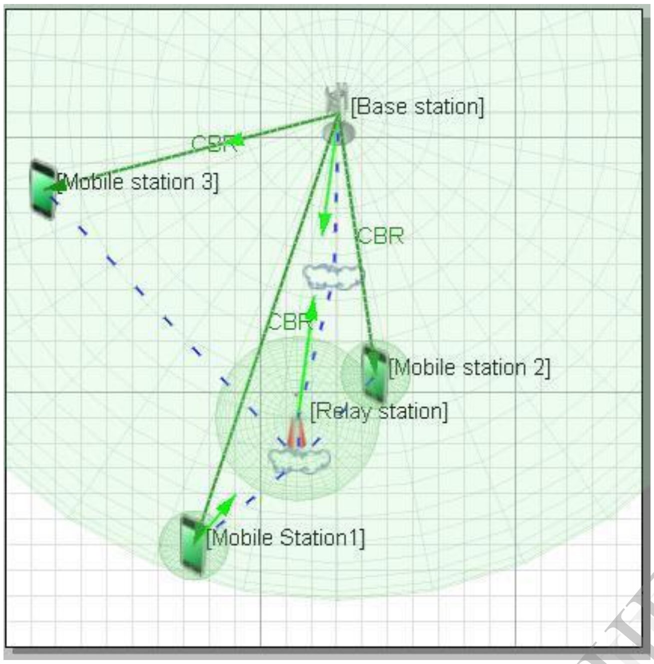

Fig 2.Qualnet Simulation scenario of small cell network

Fig.2. shows the proposed system scenario, containing a base station connected to three mobile stations relay station (small cell). The performance of the model has been analyzed with constant bit rate (CBR). The figure also shows the CBR traffic application. The three mobile stations move from its location on the waypoint with random mobility within the terrain area. The simulation time for the scenarios is of 100 minutes. The total items sent during the simulation time are 100 and each item size is of 512 bytes.

B. Network Specifications

The Table I shows the simulation specification for the two scenario created on Qualnet simulator.

TABLE I. SIMULATION PARAMETERS

Parameters	**Value**
Terrain dimensions	2500x2500m^2
Physical layer	802.11b
Network layer	IPv4
Routing protocol	AODV
Propagation model	Two ray
Channel Fading Model	Rician fading
BS transmit power/ BS height	46dbm/32m
RS transmit power/ RS height	27dbm/5m
MS transmit power/ MS height	15dbm/1.5m
Frequencies	1.8GHz & 2.4GHz

III. BATTERY MODELING

The issue of energy saving is significant since in a battery operated wireless node, the battery energy is finite and a node can only transmit a finite number of bits. The maximum number of bits that can be sent is defined by the total battery energy divided by the required energy per bit.Battery models capture the characteristics of real-life batteries, and can be used to predict their performance under various conditions of charge/discharge. Battery models are useful tools for a battery-driven system design methodology, because they enable analysis of the discharge behavior of the battery under different design choices (for example, system architectures, power management policies, and transmission power control), without resorting to time consuming (and expensive) prototyping and

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Battery provides voltage and current for the components attached to the battery such as radio interfaces, CPU, Memory blocks, sensing core, etc. A DC-DC converter regulates voltage for different components as in Fig 3. Battery is a repository of electrical charges which losses its charge when a load (electrical current) is taken off from it. The loss rate is a function of the load.

The total energy consumed by the system per cycle is the sum of energies consumed by the radio transceivers (ETrans) protocol processor (ECPU), the DC-DC converter (EDC) and the efficiency losses in the battery (EBat). The total energy consumed during the execution of the software on a given hardware architecture is the sum of the energies consumed during each cycle.

$$E_{Cycle} = E_{Trans} + E_{CPU} + E_{DC} + E_{Bat}$$

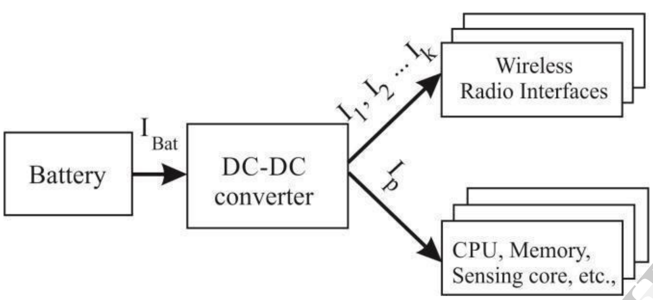

Fig. 3. System level block of smart batteries

In terms of flexibility, the electro-chemical models are the least flexible, making it difficult to use them for modeling any given battery. On the other hand, configuring the circuit level models, analytical models and the stochastic models for different types of batteries is relatively easy [8].The model used here is residual life battery which estimates the remaining service life of the battery at any time in the simulation.

TABLE II. BATTERY SPECIFICATIONS

Battery model	Residual Service Life Estimat
Battery supply observing period	1 minute
Battery type	AA - Base Station and Rel Station AAA - Mobile Station

IV.PERFORMANCE METRIC

A. End-To-End Delay

The average end-to-end delay specifies the packet is transmitting from source to destination and calculates the difference between send times and received times. Delays due to route discovery, queuing, propagation and transfer time are included in the delay metric.

(2)

Where, transmission delay of a packet = (time packet received at server – time packet transmitted at client), where the times are in seconds.

B. Throughput

Throughput is the average rate of successful data packets received at destination over a communication channel. It is usually measured in bits per second (bps) and sometimes in data packets per second.

(3)

C. Average Jitter

The Jitter is the deviation in the time among packets arriving at the destination side, caused by network congestion, timing drift, or route changes. It signifies the packets from the source till they reach their destination with different delays.

(4)

Where, packet jitter = transmission delay of the current packet - transmission delay of the previous packet. Jitter can be computed only if at least two packets have been received.

V.RESULTS AND DISCUSSION

The simulation was carried out for both the scenarios using Qualnet simulator. The results obtained by the Qualnet Analyzer are analyzed based on their performance metrics.

A. Comparison of Residual Power levels

The net power saving in mobile stations in milliampere-hours is estimated as,

(5)

Where, P_{RS}, P_{ES} are relay scenario and existing scenario residual battery level respectively.

The power saving per hour is obtained by,

(6)

Where, V_S is supply voltage interface for mobile stations, 3V.
The power in dBm is given by,

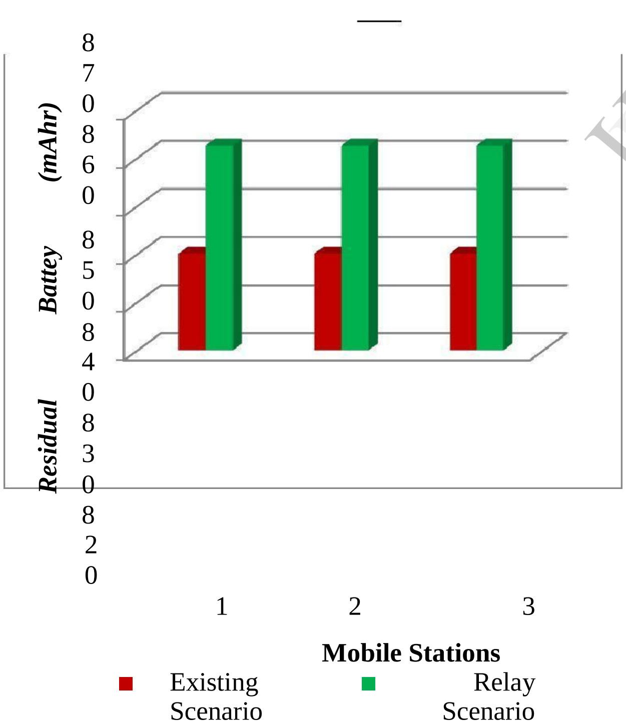

Fig. 4. Comparison of Residual Power levels

From the fig 4. we can conclude that, when the relay station is introduced, average residual power in the mobile stations increases to 862 mAhr from the conventional system with average residual power 840 mAhr. Thus, the overall power saving is computed using the equations (5), (6) and (7) and it is obtained as 18.2dBm

B. Throughput Comparison

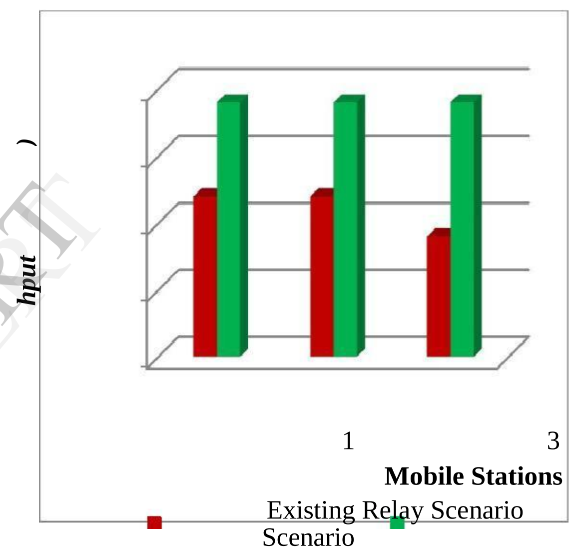

Fig. 5. Comparison of Throughput

The above fig 5. shows comparison of the throughput between the two scenarios. The throughput values were obtained from the simulator using the equation (3). When the relay station is introduced, the average throughput of the mobile stations increases to 69 bits per second from an average of 60bits per second in the conventional system.

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C. Average End to End Delay Comparison

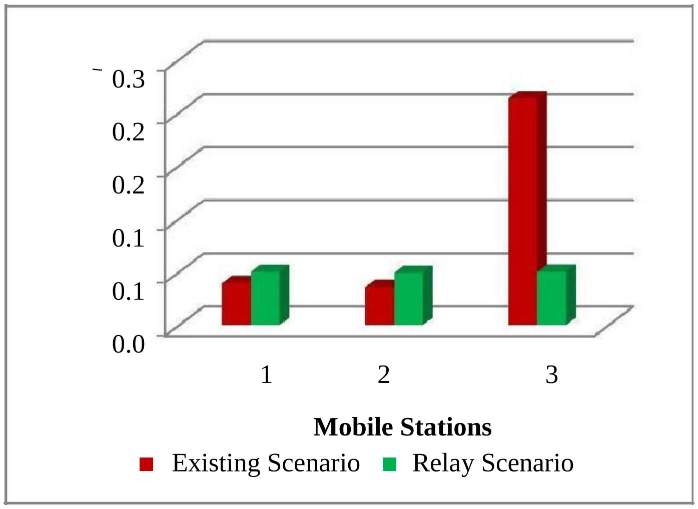

Fig. 6. Comparison of End to End delay

After the relay station is introduced, the mobile stations 1 and 2 are of high mobility the end to end delay remains more or less the same but the mobile station 3 with minimum mobility experiences a very limited end to end delay.

D. Average Jitter Comparison

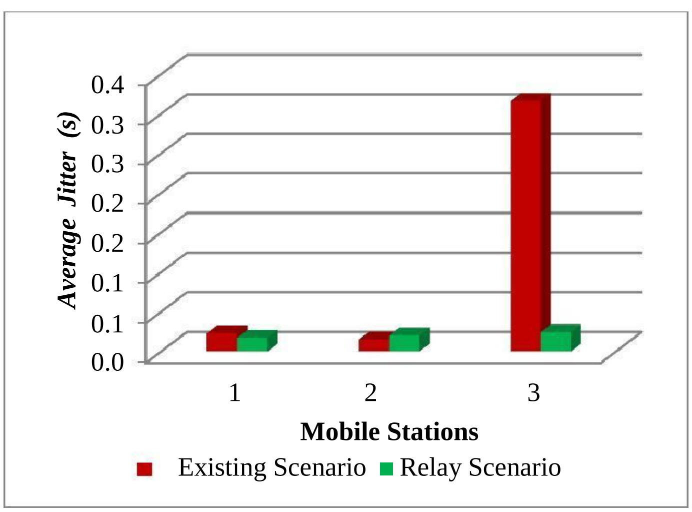

Fig. 7. Comparison of Average Jitter

In the above Fig. 7, when the relay station is introduced, the average jitter of the mobile stations decreases considerably than in the existing scenario. Even with same velocity due to the random mobility, the mobile node 1 and 2 the jitter varies minimal. But as the mobile station 3 stays around the relay station for ample time, also with minimum mobility, it experiences a very little jitter. The value of average jitter for each mobile station in each scenario is evaluated from the equation (6).

VI. CONCLUSION

Here, from the analysis from the battery consumption performance from the two scenarios discussed we obtain a net gain of 18.2 dBm of power saving and hence it can be observed that the relay scenario is more efficient compared to the conventional approach of macro-cell network. The comparison results denote that the small cell network has implemented substantial enhancement in the case of Residual power level and Throughput. Also in the case of typical mobility, there is considerable decrease in Average jitter and Average end to end delay.

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