Spectral Efficient Compression and Aggregation Technique in Macro-Femto Heterogeneous Network

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***Abstract*—Mobile femtocell (MFemtocell) assisted cellular network is mostly considered for the energy efficient system. But this adds the problem for its spectral efficiency as there happens to have a trade-off between energy efficiency and spectral efficiency in MFemtocell assisted cellular network. Mainly works related to resource allocation strategies have been preferred when it comes to improve spectral efficiency of the system. Getting motivation from wireless sensor network scenario, a spectral efficient compression sensing (SECS) is proposed which is derived from the compress sensing (CS) technique to work for the betterment of spectral efficiency of the macro-femto heterogeneous network. Simulation results for spectral efficiency of the system applied with proposed methodology is evaluated and compared with the non compressed and non aggregated macro-femto heterogeneous network.**

***Index Terms*—Spectral efficiency, macro-femto heterogeneous network, compression and aggregation technique**

INTRODUCTION

In the past decades, huge work has been done to increase capacity of network to cope up with the exponential increase in data traffic caused by a new generation of heterogeneous networks. Various methodologies are proposed in cellular networks, such as macrocell, microcell relay, and macro-femto heterogeneous networks which have been researched to enhance the capacity such as spectral efficiency and increase the coverage of such wireless networks. Techniques like orthogonal frequency multiplexing technique (OFDM) and multiple input multiple output (MIMO) are proposed to improve this spectrum efficiency. Novel resource allocation strategies and resource management schemes have also been put forward for the same. A recent addition to it is femtocells, which are installed by user for better indoor data and voice reception. They are mainly low power, small size, low cost, short range base station serving limited number of users. While these femtocells uses the previously available infrastructure to its usage such as modem, digital subscriber line or radio frequency link which is called as backhaul link. As per our previous work [1] a novel method is used to design the macro-femto heterogeneous network which serves more as an energy efficient system. This happens due to reducing of the distance between transmitter and receiver. But according to paper [2], there is a significant trade-off between this energy efficiency and spectral efficiency in this femtocell assisted cellular network. For regular cellular mobile system, researchers have limited their scope of improving spectrum efficiency to the work related mostly in resource allocation strategies and their management.

So we will first briefly review the work that has been done till now for increasing the spectral efficiency of the femtocell assisted cellular network. Paper [3] and [4] discusses the idea of resource scheduling for increasing the spectral efficiency in two tier femtocell assisted cellular OFDM network. But it comes with its own problem like interferences. Paper [5] and [6] uses reinforcement learning to adapt to the surrounding conditions so that resource allocation can be done promptly. This only helps for the betterment of the edge spectral efficiency than the overall spectral efficiency. To overcome shortcomings like interference management and overall spectral efficiency of the network as above, paper [7] uses fractional frequency reuse (FFR) scheme. So it is evident that the work on resource allocation strategies is preferred for the improvement of spectral efficiency. Using the concept of compression and aggregation in wireless sensor network, one can work for reducing the number of bits through the given bandwidth to improve the spectral efficiency.

When we talk about data redundancy, various works shows compression and aggregation techniques applied at the application layer. As discussed in papers [8] [9] [10] and [11], most of the redundancy is present at packet level which remains untouched at the application layer. Some initiative work has been done for redundancy reduction at the network layer in [12] where memory assisted gateways are used. This requires system to have extra helper nodes increasing the load on the system. Also in our previous work [13], we surveyed various techniques that have been used to work for the enhancement of spectral efficiency of cellular system. So by keeping in mind all above related work, compress sensing technique is used to propose SECS into our previous work of macro-femto heterogeneous network. This will provide data redundancy elimination at the network layer itself proving better spectral efficiency of the network. So remaining paper is arranged as follows. Section II gives the description of redundancy elimination in wireless network. Section III consist of system model and proposed methodology section IV concludes the paper with the simulation results.

ELIMINATION OF DATA REDUNDANCY IN WIRELESS NETWORK

Spectral efficiency is very vital parameter of wireless communication. It progressively needs intentness as operators are required to handle this much large data through limited bandwidth and look for the aid to minimize the added cost of transmission for it. One way of solving it is by reducing the data bits transmitting through limited bandwidth. This can be achieved by elimination of data redundancy through the highly traffic network. This include different wireless link such as mobile access point to the mobile client and mobile access points to base stations. Broadly redundancy can be studied in two aspects, first being data redundancy and second being client redundancy. As our main source of motivation for using compression and aggregation technique in macro-femto heterogeneous network is taken from wireless sensor network, client type of redundancy is required to be studied in it. This will eliminate the redundant data being collected at sink node from various wireless sensor nodes in the network.

Now considering data redundancy in the IP layer, 60% of total bandwidth can be saved through data redundancy elimination [14]. Also study shows that 50% of inter client redundancy adds up to the network [15]. So it is evident that the data redundancy elimination is very important for better spectral efficiency of the network. This requires special attention to carry out the compression and aggregation method derived according to the designing of network in which it needed to be implemented. The proposed SECS is used for compression and single value decomposition technique is used for the aggregation in this paper. Further in section III, system model with proposed methodology is discussed.

SYSTEM MODEL

System Topology

Now femtocell can be of two types, first is open access and second one is closed access. Open access is mainly used for public places like airport and closed access is used for private users like offices. For the sake of the MFemtocell which will be mainly deployed on buses and trains, we used open access femtocell network. As proposed in our previous paper [1], we have considered a single microcell in which multiple MFemtocells have been deployed. Let D = {1, 2.., D} be the total number of end users that communicate directly with the base station of microcell. Let M_k be the total number of evenly distributed end users into the k MFemtocells where $k \in K$ = {1, 2.., K}. So U be the total number of end user which can be given as $\sum_k M_k + D = U$.

As shown in fig. 1, mobile nodes are the end users which may come under femtocells or macrocells. Direct link is used to connect the macrocells normal nodes to the base station whereas the access user of femtocells are connected to femtocell access point (FPA) by access link. Then these FPA uses the existing cellular network link which is also called as backhaul link to connect to the base station of macrocell.

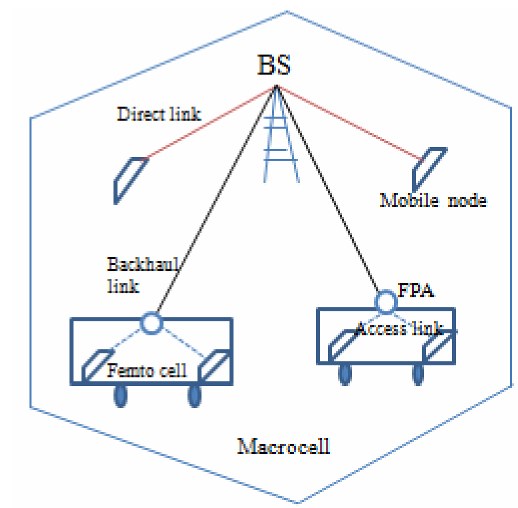

Fig. 1. System model: Macro-femto heterogeneous network [1] [10].

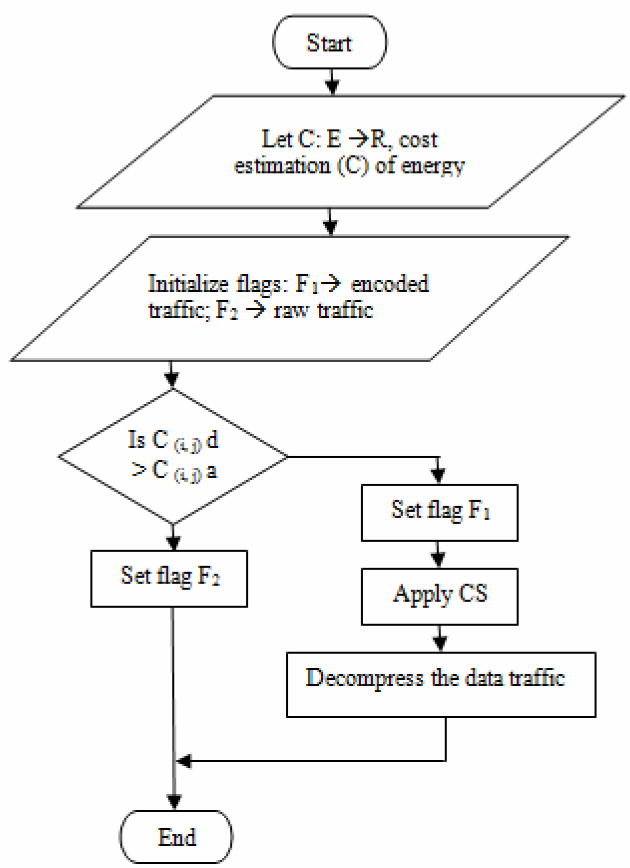

Fig. 2. Proposed SECS methodology flowchart

Proposed Methodology

As the network considered is macro-femto heterogeneous network, one can interpret from it that the node which was then previously attached to macrocell can have its connectivity to FPA now as it is in the femtocell. In this network, we used the link quality parameter to check whether the access link quality L_{qa} is better than direct link L_{qd} connecting to the same node. If it is not then while being in the femtocell, it will have its connectivity through macrocell network.

Consider the whole network as graph G (N, L) such that N are the nodes and L denotes the links connecting these all N nodes in this macro-femto heterogeneous network. Consider C:E□R, be the cost estimation in terms of energy expenses, where E is the energy expense required to carry out unit data across the link (i, j), hence L Є (i,j). So this cost estimation in terms of energy expense can be define as $C_{(i,j)}$.We are defining this cost estimation to carry out the compression by CS technique and aggregation by SVD in a such way that it can be made cost efficient and compatible to the macro-femto heterogeneous network. So as explained earlier the design of macro-femto heterogeneous network, when the node will be in femtocell and the L_{qd} is better than L_{qa}, that node will have its connectivity through base station. So the cost expense for direct link $C_{(i,j)}d$ will be lesser than cost expense for access link $C_{(i,j)}a$. So there is no need to apply for the compression and aggregation. But for vice versa case, node will be connecting through femtocell access point and then we can apply compression and aggregation for the access link. As this methodology works for the betterment of spectral efficiency, it can be termed as SECS. Flowchart for above explain methodology is shown in fig. 2.The Pseudo code for the same can be given as follows

1. *Initialize*
   G (N, L); N = nodes; L =links, L Є (i.j).
2. *Define*
   C:E □ R, C = cost estimation; E = energy expense per unit data
3. *Initialize*
   F_1 = Encoded traffic data, F_2 = Raw traffic data
4. *If $C_{(i,j)}d > C_{(i,j)}a$, then*
   Set flag F_2 and jump to step 7.
   Else
   Set flag F_1
5. *Apply CS through FPA*
6. *Decompress the data traffic at receiver*
7. *Terminate*

Simulation Result

To obtain the spectral efficiency computation model of this maco-femto heterogeneous network, we ran the proposed methodology based network through network simulator 2 (NS2). It uses predefined set of parameters such as omnidirectional antennas, network interface types, AOMDV protocol. Here flat grid topology is used to create the scenario on NS2. As per designed, we created single macrocell consisting multiple MFemtocell. Here 20 femtocell nodes and 10 normal nodes are taken. Also the number of femtocell node in each node is pre decided which is 4. So we get the total 5 number of femtocell that needed to be implemented. The nodes are randomly deployed over flat grid with random energy assign to them. Base station is deployed at the centre of the grid. Being the base station, highest energy among all nodes is assigned to it. FPA among each femtocell are decided by comparing energies of each node in that femtocell and the highest one is elected to be FPA. Some of the parameters required while doing simulation are tabulated with their values in table 1. as follows.

Table 1. Simulation parameters and their values

Parameters	Values
No. of nodes	30
Area size	300 X 300
Mac	802.11
Simulation time	50 sec
Traffic source	CBR
Packet size	1000
Routing protocol	AODV
Packet interval	0.01 sec

While reducing the redundant data, parameters like time delay, throughput of the system and the number of packets transferred while communication can be calculated. So fig. 3. compares the time delay for carrying out the communication which clearly proves the less delay for the proposed system.

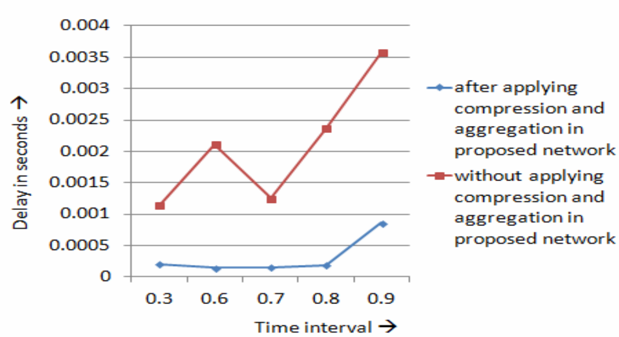

Fig. 3. Time delay for the transmission of data

The throughput of this network can be analysed for proposes network. Here fig. 5. shows the increase in the throughput value at 0.7 second. The throughput value at that instant found out to be 45 after application of aggregation and compression to proposed network which is greater than the value of 30. The vital finding of compression and aggregation evaluation is to calculate the total number of packets being transferred as shown in fig. 6. Before applying compression and aggregation to the proposed network the number of packets found out to be 0.9 at the instant of 0.3 second which was higher than the 0.6 after application of compression and aggregation.

First SVD carries out the lossy aggregation of the data traffic. The threshold aggregating value for the simulation is kept to 2. Any value varying less than the threshold value will be rejected. This aggregation is not lossless. The data traffic that got rejected in aggregation are unable to recover. After this the proposed SECS is applied and the data at the receiver are able recover by using the decompression technique of CS. So

this results in elimination of data redundancy in the network layer itself. This can be verified by the calculating ultimate goal of this paper to enhance the spectral efficiency which can be calculated as

$$\eta = C_{ch} / BW$$

Here η defines the spectral efficiency in kbs/Hz whereas C_{ch} and BW are the channel throughput and channel bandwidth respectively. Now for the analysis of the simulation result of spectrum efficiency, we compare the result of spectrum efficiency of different communication link with and without the application of compression and aggregation. As explained earlier, we are able to analyze the result for four different communication link which are femtocell to femtocell node, femtocell to normal node, normal node to femtocell node and normal node to normal node. We carried out 15 number of iteration for each type of communication link after taking mean of those 15 iterations the value obtained is plotted as shown in fig. 3. So the spectral efficiency for the macro-femto heterogeneous network with application of propos methodology is found out to be 28% better than that of network without application of compression and aggregation.

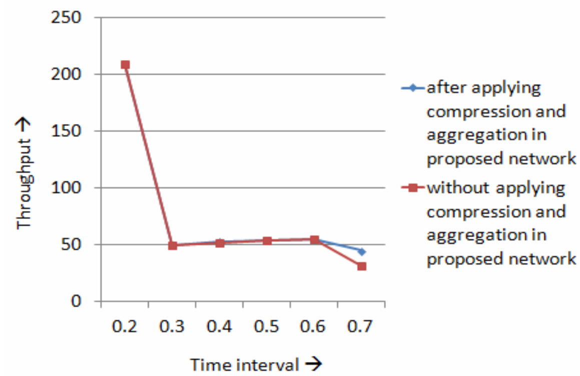

Fig. 5. Throughput of the network

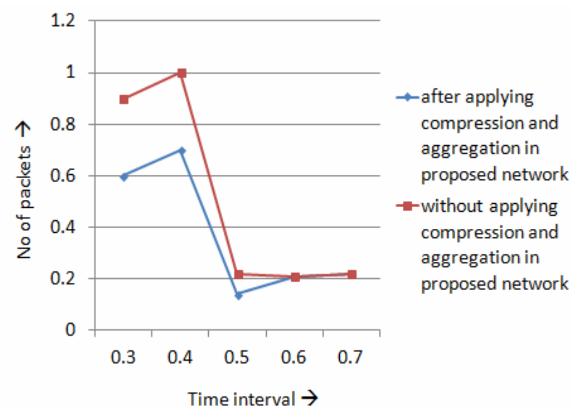

Fig. 6. Number of packets transferred

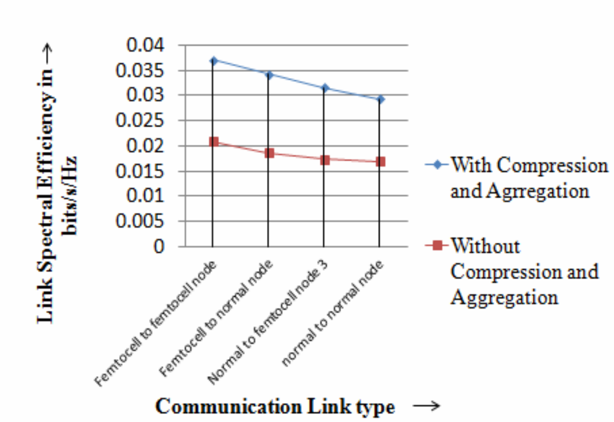

Fig. 4. Link spectral efficiency with and without applying compression and aggregation

Conclusion

So right from the start, we discuss the significance of data redundancy elimination which is then incorporated in macro-femto heterogeneous network. After that we proposed a methodology SECS to apply CS to this network with p cost efficiency. This causes the network to be more spectrally efficient by elimination of data redundancy at the network layer where most of data redundancy occurs. In the end it came to notice that, a significant amount of spectrum can be made efficient by applying compression and aggregation at the network or packeting layer itself rather than at application layer.

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