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Multi-hop Cellular Networks for Load Balancing and Interference Coordination Using OFDMA

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ABSTRACT: Multi hop cellular networks (MCNs) use multiple low-power transmitters for high throughput and coverage of large area in a network. The network consists of Base stations (BSs) and Relay Stations (RSs) placed inside the center and edge of the network that could transmit the frequency simultaneously. The network performance can be affected by the mobile stations which lead to co channel interference (CCI) near the coverage boundary of the cell. The traffic quality and the quality of service (QOS) can hardly be guaranteed due to the unbalanced user distribution. The static method is used which divides the network into a tri-sector network according to the frequency reuse scheme that works with the downlink of OFDMA-based specification. The throughput increases by accommodating more users in the coverage area in a MCNs. Interference in the cell edge is avoided by implementing the avoidance algorithms where the base stations are placed in the centre of the cell and in tri-sector of the network.

KEYWORDS: Multi hop cellular network, co channel interference, OFDMA, Interference avoidance, Frequency reuse, Load balancing, Handover

I. INTRODUCTION

The combination of an appropriate candidate network and air-interface technology provides opportunities in relay networks. Cellular network provides reliable and high data rate coverage within and outside the cell. Orthogonal Frequency Division Multiple Access (OFDMA) technology, the foremost promising physical layer technology for the fourth generation (4G) wireless network specification offers a sophisticated air interface operation in multi-hop cellular networks (MCNs). The OFDMA instrumentation that supports bequest network give services with extended coverage and high rate by new relay methods and technologies that meets cellular layer necessities. Fixed relay stations (RSs) are deployed for less functional poor channel conditioned base stations (BSs) in MCNs. The radio resource allocation scheme overcomes the limitations of network collision on relay transmitters (BS-RS links).

Due to inter-cell and intra-cell frequency reuse scheme in MCNs, RSs periodically use a similar spectrum as MSs or BSs which relates radio resource allocation scheme in OFDMA systems. This helps accomplish higher cell edge performance and easier interference management for higher frequency. RSs enhance the signal strength of the nodes close to the boundary of relay station by transmitting two signals to decrease the capacity of the system. One transmission is from the base station to the relay station and the other is from the relay station to the mobile stations. The relay selection controls the throughput and strength of signal to check the appearance of two-hop transmission and to achieve highest system capacity in an optimal relay location.

The organization of the paper is as follows. Section 2 briefs the wrap cellular network model in a traditional work and its limitations are analysed under related works. Section 3 details the design and rationale of introducing the proposed framework. Positional interference avoidance algorithm under proposed work is comparatively analyzed with existing algorithms under Section 4. Experimental setup and result is evaluated under Section 5. Section 6 summarizes the conclusion and possible enhancement in future scope.

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II. RELATED WORK

In [1], the existence of base station and relay station within the network transmission hides massive areas in large cellular network. Here the network is divided into 6 cells where the base station is placed in central cell that passes traffic to the mobile switching centre through radio interface. Mobile switching centre [3] coordinates and arranges base station channels in step with the transmission and affiliation of a network. The relay station is often placed for each cell or it is often placed for 2 cells in step with the convenience of the network. The packets are transmitted through an uplink and a downlink within the channel. The base station sends system packets to all mobile station which is done by the control channel of the cellular network. The header of these packets contains the information about the available channels in the cell and its corresponding frequency.

In [2] wrap cellular network model each cell is divided into 7 sectors deployed in a coverage area of a network. The base station antenna is placed in each sector which communicates and transfers packets of information through radio interface. In a radio network [7], the number of simultaneous calls is controlled by the available frequency spectrum and available bandwidth is allocated to the number of channels in each sector. In a cellular system frequency re-use is achieved by the available base station channels and separation of transmitters from other users at the same frequency is allowed. Factor 3 or 7 is used in the frequency reuse pattern [5] to reduce CCI is used in traditional single-hop cellular networks (SCNs) with low spectral efficiency. Frequency planning with reuse factor of 1 in CCI is likely to degrade the performance at cell boundaries. Hence, sector-level algorithm is implemented for chunk restriction in a network whereas central algorithm restricts conflicting requests in each sector of a cellular network.

III. PROPOSED SYSTEM

The frequency resource allocation and transmission of packets in the relay stations is not well addressed in the dynamic network. In traditional systems there is no division of cells during the resource allocation which leads to overload and under load of cells. Hence, a reuse scheme with a micro cellular model is proposed that overcomes the load balancing problem and inter-cell handover of signal. To brief the proposed approach each cell in a multi hop network is subdivided into micro cellular units on receipt of particular frequency resource using soft frequency or partial frequency reuse scheme. Post cell partition, a sector level interference algorithm and central level interference algorithm deployed on two different base stations coordinates with the mobility nodes to optimize the handover of signals especially on the edges.

The architecture diagram Fig. 1 shows the node placement, the incorporation of path control and device control in proposed network. The resource request entity is installed for the inter node communication using transmission control

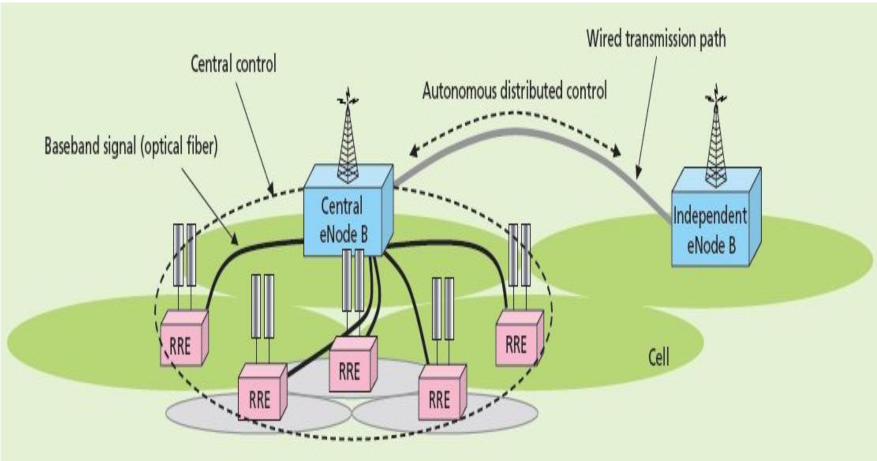

Fig. 1 Independent node configuration and RRE configuration in the proposed system

systems.

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A. *Soft Frequency Reuse and Partial Frequency Reuse:*

The zone based reuse factors used by the Soft Frequency Reuse (SFR) vary from Fractional Frequency Reuse scheme located in the center and edge of the cellular topology. The zones in SFR are restricted with the allocation of frequency and power. In soft reuse, the scheme's effectiveness can be adjusted by dividing the power of the frequency bands located in the edge as well as center of the cell. SFR is proposed with 3GPP LTE framework to enhance the services near the cell boundary. The cell edge band uses 1/3 of the available spectrum as shown in Fig. 2.a, the structure of cluster size of 3 for 3-sector cell sites is formed to the neighboring cells.

The cell centre band is composed of frequencies used in the outer zone of the neighboring sectors in the minor band. Each group in the major band is assigned with the transmission power which depends on the desired effective reuse factor and keeps the total transmission power fixed with the higher transmit power. The major band is used in the cell center as well when the cell edge user terminals do not occupy it whereas the minor band can be used in the center of the cell. Due to this scheduling restriction, the power ratio can be adjusted from 0 to 1 effectively as SFR is used as a compromise between reuse of 1 and 3 with the trisector base stations in a network. User terminals are categorized as cell edge and cell center determined by the received signal based on user geometry.

Contrary to SFR, partial frequency reuse (PFR) is used to restrict portion of the resources in the cell sector so that the network does not use some frequencies. In the Fig. 2.b, the available system bandwidth is assumed as β which divides into inner zone and outer zone with bandwidth β_i and β_o respectively. The inner and outer zone is used with the reuse factor of 1 and for β_o, the reuse factor of 3 is used for the trisector base stations located in the outer zone of the network. The effective frequency reuse factor for this reuse scheme is given by $\beta/(\beta_i + (\beta_0/3)$, hence PFR scheme always attains value greater than 1 as an reuse factor. The power used for frequencies can be amplified for reuse pattern in the outer zone.

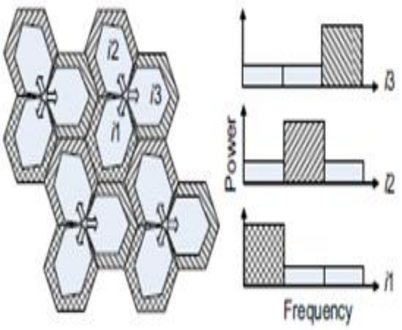

Fig. 2.a Soft Frequency Reuse

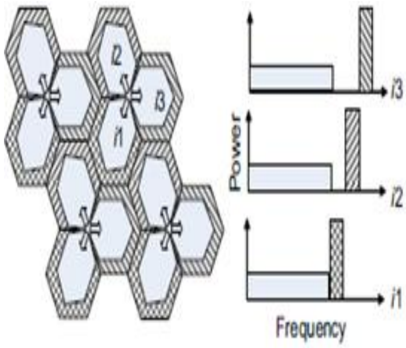

Fig. 2.b Partial Frequency Reuse

IV. INTERFERENCE AVOIDANCE SCHEME

Interference occurs in the cellular network when transmission takes place between the cell and cell edge. It can be handled by the classical clustering technique, frequency reuse scheme. The resource can be partitioned using this clustering technique and also reduces interference in the cell edge user terminals in the network. Interference management acts as a key concept for designing the data rate wireless systems in the future which is required for employing dense reuse of spectrum.

Inter cell coordination is done by proposing a novel dynamic interference avoidance scheme and it prevents large amount of inter cell interference in the cells. A network is divided into cells whereas individual cell comprises of base station and relay stations according to the transmissions across the network. The base station can be placed for each cell and relay station for needed communication between the cells.

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The resource can be switched from congested to non-congested stations to achieve load balancing in the cells. When relay station gets overloaded and if it does not contain enough frequency resource, some users can be switched from congested to non-congested base stations in the same sector by the handover mechanism in order to reduce traffic across the network as well as to reduce the probability of blocking in the network. The users associated with one relay station cannot establish connection with the other relay station in the same sector that limits the low transmission power in the network. Most of the resources for the users linked with the respective relay stations are stored by the handover mechanism by using two-hop transmission whereas a single-hop transmission was used early in the relay stations.

Interference avoidance algorithms:

As shown in Fig. 4, a network which consists of 19 BS each with 3 hexagonal sectors is taken into consideration. The Omni-directional antennas are considered to receive user terminals while the sectors are equipped with 1200 directional transmit antennas. Also an assumption is done with the system that uses the orthogonal reference signals in the specific cells. The UTs are able to determine the interference separately through this reference signal of neighbouring first tier sectors in the corresponding cells. It is inferred that one of the first tier sectors in downlink transmission among any sectors in UT is the most powerful of interferer.

In Fig. 4, an example of antenna directivity is considered in relative locations, the BSs may receive the most dominant interference from sector 2 or 3 from a cell-edge UT in sector 1 of BS1, or from sector 2 or 3 of BS2, or from sector 3 of BS3, or from sector 2 of BS7. UTs may experience severe interference from the neighbouring sectors of own cell which are closer to the serving sector and the significant interference is received by the cell-edge UT from the sectors of the nearby cells and also experience the higher path-loss. The total throughput can be of less attractive when BSs are closer to the cell whereas an optimal or sub-optimal allocation scheme is considered to maximize the network throughput in the network. The maximum of interference is avoided by using these UTs which maximizes the throughput across the cell-edge and cell-centre.

1) Sector-level algorithm

Sector-level algorithm considers chunk restriction requests and utility matrix for all first-tier interferers. The UT demands and channel conditions derives the threshold-based restrictions which is used to prepare the utility matrix. An iterative Hungarian algorithm is used to prepare the restriction request from the tentative chunk-to-UT allocation scheme.

a) *Utility matrix formation:*

The utility matrix in sector i is made by the subsequent steps that area unit recurrent for every UT m and every chunk n

- Dominant interferer's area unit sorted into a dominant interferer set.
- For UT m and chunk n, the conditional SINRs is given by $\gamma^{(i)}{}_{m,n}|\Psi=\{\ \}$, $\gamma^{(i)}{}_{m,n}|\Psi=\{\psi_1\}$, and $\gamma^{(i)}{}_{m,n}|\Psi=\{\psi_1,\psi_2\}$, that correspond to restrictions of 1, 2 and none of the foremost dominant interferers.
- The achievable rates for the above SINRs are determined by restricting the chunks assigned to UT in m and n respectively.
- Achievable rates $^{(i)}{}_{,}$ are calculated by finding the inter-cell dominant interferences which is to be restricted on each chunk and UT.

a) *Hungarian algorithm for restriction requests:*

In order to prepare chunk restriction requests, iteratively an Hungarian algorithm is applied to $^{(i)}{}_{\times N}$ as it reserves chunks for each UT and it is done by the following steps.

- $U^{(i)}{}_{M\times N.}$ As M<<N, a maximum of M chunks in Hungarian algorithm is applied by allocating corresponding M, that yields the maximum utility in UTs.
- Among M chunks, an arbitrary chunk is chosen in a UT and if a restriction is marked upon it, it will be placed in the restriction list for the corresponding interferer.

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- The Hungarian algorithm is run on the updated table which belongs to the chosen entries from the columns of the terminals and it can be deleted from $^{(i)}{}_{\times N}$.
- The steps 2 and 3 are repeated until all the chunks are tentatively allocated to UTs.

These requests are forwarded to the central controller where each sector consists of a list of chunks to be restricted in each of its neighbouring sectors.

Utility Matrix Formation

for $m = 1{:}M$ **loop**
for $n = 1{:}N$ **loop**
$\Psi \leftarrow \{\ \}$;
Calculate $\gamma_{m,n}|\Psi=\{\ \}$ and $r_{m,n}|\Psi=\{\ \}$ with $I^{(k)}{}_n = 1$; $\forall k$;
$\Psi \leftarrow \{\psi_1\}$;
Calculate $\gamma_{m,n}|\Psi=\{\psi_1\}$ and $r_{m,n}|\Psi=\{\psi_1\}$ with $I^{(k)}{}_n = 0$ for $k \in \Psi$; $I^{(k)}{}_n = 1$,
$\Psi \leftarrow \{\psi_1, \psi_2\}$;
Calculate $\gamma_{m,n}|\Psi=\{\psi_1,\psi_2\}$ and $r_{m,n}|\Psi=\{\psi_1,\psi_2\}$ with $I^{(k)}{}_n = 0$ for $k \in \Psi$; $I^{(k)}{}_n = 1$, otherwise;
if $r_{m,n}|\Psi=\{\psi_1\} \geq r_{m,n}|\Psi=\{\ \} + r^{TH}{}_m$ **then**
ψ_1 is restricted in chunk n
end if
if $r_{m,n}|\Psi=\{\psi_1,\psi_2\} \geq r_{m,n}|\Psi=\{\psi_1\} + r^{TH}{}_m$ **then**
Chunk n is marked to be restricted in ψ_2
end if
end for
end for

Chunk Restriction Request preparation

Initialize restriction request $\mathcal{R}_k = \{\ \}$; $\forall k$;
Initialize $\mathcal{U} = 1 \cdots N$
$N' \leftarrow N$, where N' is the number of unallocated chunks
while $\mathcal{U} \neq \{\ \}$ **loop**
Hungarian algorithm is applied to $U_{M\times N'}$
If k^{th} sector of the chunk C is allocated **then**
Update $\mathcal{R}_k$
end if
$U_{M\times N'}$ columns are removed corresponding to C
$N' \leftarrow N' - N_{\text{allocated}}$
end while

2) Central-Level Algorithm

The central controller of the central algorithm will receive requests from BSs which forms a cluster of network and the particular chunk can be resolved by the conflicting requests in an optimal manner. The algorithm is able to resolve any conflicting restriction requests and it prepares a list for each sector in the final restriction. The Fig. 5 shows an example to solve the problem of central controller using the algorithm. The dashed and solid arrow lines depict interference received at the originating and head sectors based on which it is either accepted or rejected the corresponding sectors. For some chunks, the interference can be tolerated by sector B from sector A and the opposite is not possible because it consists of dashed arrow towards sector B from sector A for some requests.

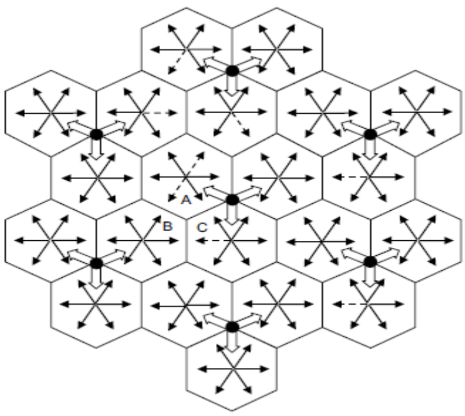

Fig. 4 Sector level placement

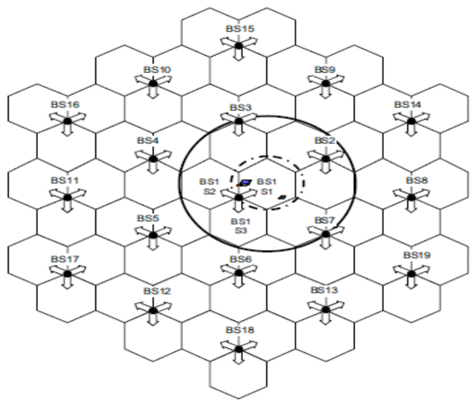

Fig. 5 Central level placement

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V. Performance Evaluation

The proposed positional interference scheme is compared with two conventional approaches known as dynamic interference scheme and joint interference scheme. The metrics for evaluation include End-to-End latency, Handoff latency, Packet loss and Throughput and results are shown in Fig.6, Fig. 7, Fig. 8 and Fig. 9 respectively. The comparison of number of static coordination schemes is done with the proposed scheme and its performance is analysed. It shows that the throughput can be achieved in the cell-edge by using the static coordination schemes and it has only a significant loss in sector throughput.

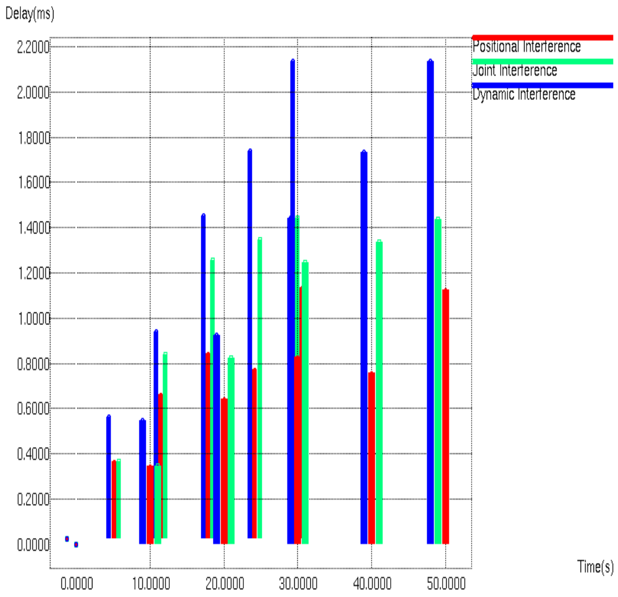

Fig. 6 End to End latency comparison

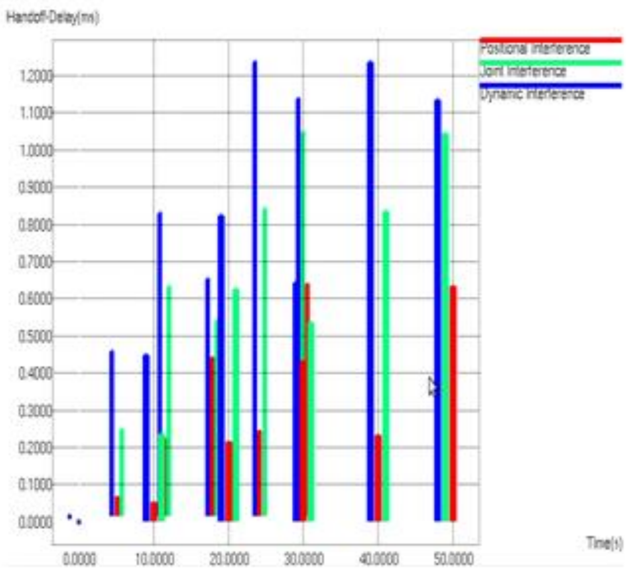

Fig. 7 Handoff latency in interference

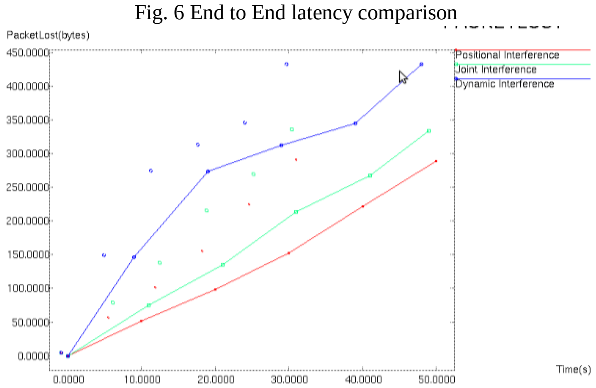

Fig. 8 End to End latency comparison

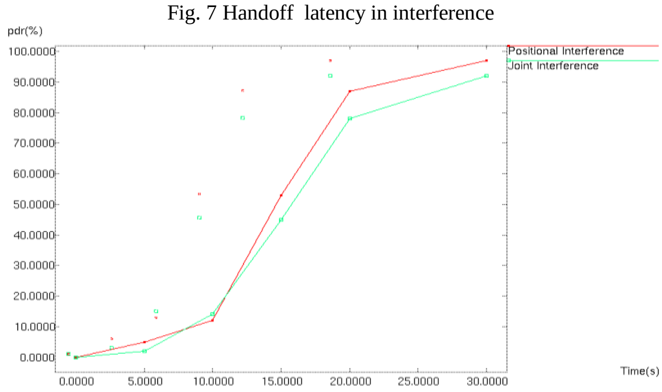

Fig. 8 Throughput comparison

VI. Conclusion and Future Work

A quantitative study on an adaptive resource allocation scheme based on interference coordination and load balancing for multihop cellular networks have been carried out. The formation of cells in a network is formed by the soft and partial frequency reuse scheme to maintain efficiency and for better performance. The positional interference avoidance algorithm characterizes the performance and communication of stations between the cells in a network. The simulation results proved that our proposed scheme not only satisfies the require coverage probability, but also improves the sector throughput, interference avoidance and accommodates more users. The experiment shows dynamic

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interference avoidance scheme infers that a trade-off between the performance and complexity is adjusted through the tuneable threshold function.

The implementation of frequency reuse scheme mitigates the interference and maintains high spectral efficiency, and also we presented a mechanism called practical LB-based handover which distributes the traffic load evenly and guarantee the users with quality of service. The interference avoidance method is used which improves avoidance of collision in a network. In future, this method can be implemented in more than a sector which improves the interference avoidance in large network.

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