A Novel Approach for Improved Load Balancing and Interference Reduction in Wireless Networks using OFDMA

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Abstract. The quality of service offered to the user equipment in Multihop cellular networks with proper connection is affected severely due to the fading effects. These fading effects can lead to link loss between the user equipment (UE) and base station. This problem is severe when the UE traveling inside of tunnel, forests and big buildings. The duration of the link loss may vary from seconds to hours. Link loss management can control the link loss, increase the coverage area and signal quality in cell boundaries. It requires predictive power and link scheduling in cell sectors and signal quality enhancement at cell boundaries using filters. Interference Coordination and Load Balancing at base station and UE algorithm is used. This paper introduces a link loss management algorithm with load balancing to provide seamless service to users and this increases the Quality of Service (QoS) of safety critical communications.

Keywords: Base Station, Cellular networks, Inter channel interference, Power distribution, Base station, Signal to interference plus noise ratio, MIMO channel model.

1. Introduction

Technologies for load balance between surrounding cells of a mobile wireless communication network can reduce traffic congestion and improve network system capacity. The load balancing can be achieved by changing different parameters of the radio access network. These modifications may be made at cell or adjacent cell level. The modifications can be made iteratively in response to different operational statistics gathered. The changes will change cell size and cell shape, as well as adapt the transfer to optimize system resources and the use of hardware. An iterative optimization method will obtain performance statistics and network configuration from a mobile wireless network on a regular basis. The collected information can be periodically analyzed to determine parameter adjustments. Additional capacity configuration from the communication network can prevent or significantly delay the acquisition of additional hardware resources to mitigate device capacity problems. A widely used approach for evaluating the efficiency of a load balancing system is whether it provides a min-max balanced load solution [1]. Self-organized cellular networks include a set of functions for automated cellular network setup, optimization, and maintenance. Because mobile end-users continue to use network resources when traveling from one cell boundary to another, traffic within a cell is not constant.

Load balancing has thus become one of the most involved and evolving research fields in the Cellular Network. It includes moving the load from overloaded cells to neighboring cells with free resources for...
a more balanced distribution of the load to preserve acceptable end-user experience and network efficiency. In Multihop Cellular Network (MCN), MCN's architecture parallels that of Single-hop Cellular Networks (SCN), except that bases and mobile stations are limited in transmission range. The base and mobile stations are therefore not always available in one hop [2, 22]. In this paper, a load balancing system that only applies to a small number of algorithms is not beneficial because many new schemes will have to be built. Section 2 explains the architecture of the network, section 3 discusses interference coordination (IC) and adaptive MCN resource scheduling.

2. Related Work
Tuong Due Hoang et al. [18] discusses On mutual prioritized connection scheduling and allocation of resources for OFDMA-based wireless networks. They are classifying the user equipments into priority based user equipments and non-priority based user equipments. The link scheduling and modified power allocation algorithms will be served to the classified user equipments including link removal procedures. The link scheduling algorithm maximizes the scheduled links. The relation removal procedure is then only applied if the solution obtained from the changed power allocation could not accommodate the minimum required levels of all connections. The authors are not discussing about how to compensate for the removed links.

Guillen Femenias et al. [6] discusses about Scheduling and allocation of resources, assigning data transmission speeds, bandwidth and power optimally to the transmitter and the receiver under inaccurate channel state information. Megumi Kaneko et al. [10] gives information about resource allocation for the down link of an OFDMA based macrocell/femtocell overlaid Heterogeneous network (HetNet). In their work Femto cell base station predicts the sub-channels likely to be used in the corresponding frame by neighboring MUs based on the channel state information, Signal for interference plus ratio of noise and signal to noise. Lidong Zhang et al. [8] giving much information on resource scheduling and sharing scheme based on minimization of utility function. They are selecting a particular antenna sequence as per the channel state information at the transmitter (CSIT) for maximum spectral efficiency. They are also discussing about carrier frequency allocation to user for maximum spectral efficiency.

3. Proposed System
The proposed system addresses the problem of link loss. It executes the link loss management algorithm, when the channel becomes noisy. It manages the power in allocated channels for interference coordination and mitigation. The developed OSI model architecture gives high performance for link loss management, interference cancelation, resource allocation and power scheduling. Simulation results verify the same.
We are considering a single cell of a 19 cell MCN that has n number of user equipments and a base station at the center. The shape of the cell is hexagonal and contains three sectors. Figure 1 shows the distribution of cells in Multihop cellular networks. As per the open system reference model architecture, the components of the down link of MIMO OFDMA networks shown in Figure 2 [3, 4, 5]. Cross layer scheduler and resource allocator is a module that control time frequency resource block allocation in resource blocks. In this system the allocated bandwidth is divided into N bands according to the number of user terminals. One message will be transmitted in each band. The data link layer identifies the received messages from the network layer; then it transmits the messages to physical layer. The physical layer does multiplexing, power allocation and resource allocation. $T_N$ is the number of transmit antennas to transmit the message and $R_N$ is the number of receiving units. According to the IEEE 802.16j / m specification, the downlink subframe and uplink subframe - time division duplex frame is constructed. Sub frames are further divided into time frequency zones and each time frequency zone will be allocated to $MS - RS$ communication (access zone) or $RS - MS$ communications (relay zone) etc.

![Figure 2. Multihp Cellular Network Architecture.](image)

The standard defines two relay modes of operation. First one is transparent mode of operation in which each frame does not transmit header information. Second one is non transparent mode of operation in which each frame transmits header information instead of synchronous information. TDD frame is also called resource blocks. Cross layer scheduler allocates resource blocks to channels of MCN. This resource allocation should be compatible with frequency reuse techniques for interference coordination.

![Figure 3. TDD Frame structure.](image)
Efficient Self-Reconfiguration and Route Selection for Wireless Sensor Networks to mitigate link failures are described in [22].

3.1. Channel Model

The channel modeling needs the identification of channel coefficients which are identified from the radio signal propagation characteristics and long term and short term fading effects. Channels can be modeled based on deterministic approach and stochastic approach. Deterministic approach requires site characteristics, transmitter and receiver location, channel frequency, signal frequency and channel bandwidth. Because of the difficulties involved in the accurate estimation of channel coefficients from radio signal propagation characteristics and environment, we preferred stochastic approach to model the channels. Infinite and finite impulse response models [3, 5, 6, 20] are the examples of stochastic models.

Consider a signal vector $S = [S_1, S_2, S_3 \ldots S_n]$ at the base station and $Y = [Y_1, Y_2, Y_3 \ldots Y_n]$ is the signal vector at the mobile station. These two vectors are related by the relation

$$y = h * s + n$$

(1)

Where $h$ is a matrix which describes the characteristics of the channel and $n$ is the channel noise. The value of $h$ can be obtained as

$$H = \begin{bmatrix}
    h_{1,1} & \cdots & h_{1,n} \\
    \vdots & \ddots & \vdots \\
    h_{m,1} & \cdots & h_{m,n}
\end{bmatrix}
$$

(2)

The spatial correlation effects $R_{(m,n)}$ are incorporated in to the channel model using the below equation

$$y = R_{(m,n)} * h * S$$

(3)

The signal vector for channel $r$ $S_r$ is modeled by using the below equation

$$S_r = \sqrt{P_n} v_n(t) s_n(t)$$

Where $P_n$, $v_n(t)$ and $s_n(t)$ are the transmitted power, filter and signal component on $n$th sub channel respectively. The order of the impulse response models are selected using suitable criterions, since deviated order amplifies noises. The channel impulse response over the whole frame period $t$ can be written as

$$h_{m}^{(nR,nT)}(t)= \sum_{l=0}^{L_p-1} h_{m}^{(nR,nT)}(t) \delta(t-t_l)$$

(4.b)

In equation (4), $m$ is the sub channel number, $nR$ is the number of receivers, $nT$ is the number of transmitters, $L_p$ is the frame period and $t_l$ is the latency. The corresponding frequency response when evaluated over a sub band $m$ can be safely approximated by

$$H_{m}^{(nR,nT)}(t)= \sum_{l=0}^{L_p-1} h_{m}^{(nR,nT)}(t) e^{j2\pi f_b \tau_L}$$

(5)

Moreover, the impulse response model may not be accurate at all times due channel estimation noise. Thus noisy channel model can be modeled as

$$h_{m}^{(nR,nT)}(t)=\zeta h_{m}^{(nR,nT)}(t)+(1-\zeta)h_{m}^{(nR,nT)}(t-1)$$

(6)

Where $\zeta$ is a variable which controls the channel noise. Interference The desired signal is communing from the BS and the interference is coming from the co channels. The Interference received by the $i^{th}$ base station is affected by the distance between the base station and neighboring cells. We consider that fractional frequency reuse and sectoring has been employed to control the interference effects.
Thus the final interference calculated by equation (7) gives the interference level after interference control. As mentioned in the system model, the base station is located in the center and the interference effects are calculated by using the below equation

\[
I_i = I_{ia} + I_{ico}
\] (7.a)

Where \(I_{ia}\) is the adjacent channel interference of \(i^{th}\) cell, and \(I_{ico}\) is the co-channel interference of \(i^{th}\) cell. The adjacent channel interference can be estimated by using

\[
I_{BR} = \sum_{(i,j)} [H(B(i,j,k), R(i,j)]
\] (7.b)

In equation (8), \(B(i,j,k)\) is the base station \(k\) at \(j^{th}\) cell of \(i^{th}\) sector and \(R\) is the relay station. Cellular networks are analyzed in two levels: system level and link level. In link level, the simulation is designed to simulate the connection between MS and BS/RS. In system level, in addition to link conditions, the occurrence probability, large scale path loss, shadowing effects and relationship among multiple point to point links are modeled. Now SINR at the link between BS and RS can be calculated by using the below equation [20, 21,11]

\[
\Gamma_{(asz-br)} = (H[N_B(i,j,k),N_R] \cdot P_B)/(I_i+N_0)
\] (8.a)

Where \(H(x,y)\) denotes the channel gain between \(x\) and \(y\), \(P_B\) the power transmitted by the base station, and \(N_0\) is the channel noise. The channel gain \(H(x,y)\) can be obtained from the following equation

\[
H(x,y) = [PL(x,y)]^{(\xi(x,y)/10)} \cdot G_t(x,y) \cdot G_r(x,y)
\] (8.b)

Where \(PL(x,y)\) is the path loss between \(x\) and \(y\), \(\xi(x,y)\) is the shadow fading, \(G_t\) is the transmitter gain and \(G_r\) is the receiver gain.

Link loss management Algorithm

The algorithm is designed and given in Table 1 based on the knowledge of channel state information at the transmitter and receiver and the channel information are assumed to lie in a band. The data rates in the channel can be obtained from [8,10,2,17]

\[
R_k = \sum_{n \in N} [\log_2 (1 + \Gamma_k)]^2
\] (8.c)

Where \(k\) is the channel in \(n \in N\) channels of the system. \(\Gamma_k\) is the signal to interference plus noise ratio in \(k^{th}\) channel. Now \(l\) is the total number of available links in a system and \(l(\mathbb{T}_{h1})\) is the total number of links having \(\Gamma\) greater than \(\mathbb{T}_{h1}\). \(l(\mathbb{T}_{h2})\) is the number of links having \(\Gamma\) greater than \(\mathbb{T}_{h2}\).

Table 1. Link loss management system.
Now consider an user communicating with BS by link \( l_k^u \), after time \( t = t_1 \), if \( \Gamma_k \) is less than \( \Theta_1 \), the user equipment starts the signal transmission in two links \( l_k^u \) with data rate \( R_k \) and \( l_{(k+1)}^u \) with \( R_{(k+1)} \). After time \( t_1 \), assume that \( \Gamma_k \) less than \( t_2 \), the disconnection threshold, now the user equipment removes link \( l_k^u \) and switch to \( l_{(k+1)}^u \). Like the above, After time \( t_2 \), assume that \( \Gamma_k \) greater than \( \Theta_1 \) | \( \Theta_2 \), now the user equipment continues on link \( l_k^u \) scheduled to maximize the SINR on each channels.

The power in each channel is scheduled as follows [1, 7, 8, 9, 13, 15, 16, 18]. Let \( P_{n}^{F} \) denotes the power for sub channel \( n \) and define \( p^{F} = [[p_1^{F},p_1^{F},...,p_1^{F}]] \) Power allocation is a process of assigning power to each channel as per the channel state information. SINR is parameter of CSIT and optimum power is now the power in each channel is scheduled by.

\[
p^{OPT}_{F} = \arg\max_{p^{F}} \sum_{n=1}^{N} B \ast \log(1 + P_{n}^{F} \Gamma_n) \\
\sum_{n=1}^{N} P_{n}^{F} \leq P_{max}^{F} \\
P_{n}^{F} \geq 0 \quad \forall \ n
\]

The solution is obtained after executing an iteration algorithm for equation [9]. After determining the optimum value of \( p_{F} \), coordinated beam will be generated in the down-tilt (or) up-tilt from the base station/mobile station. Power allocation is a function the physical layer, cross layer link scheduling and resource allocation module controls the power transmitted by the transmitter. Power modified the directionality of the beam and sharpens the beam in the down-tilt and up-tilt direction.

4. Interference coordination and load balancing

4.1 Initialization

\( L, r, S_{in}, S_{out} \)

4.2 Handover execution

Wherever Step1: (measurement and report):

The BS is responsible for occasionally estimating and processing \( R_{l}^{n} (Tw) \) of the users associated with the BS. When any new user accesses the BS, the BS will compare \( R_{l}^{n} (Tw) \) with \( R_{min} \) and determine whether the BS itself is overloaded or not. Step2: (decision and execution):

If BS is overburden discovered if new users appear, To prevent substantial traffic loads, the transfer system will be implemented.

3:(final) To avoid large traffic loads, the transfer system will be executed.

5. Results and Discussion

System level and link level simulation was conducted to verify the performance of link loss management algorithm. The system level and link level simulations accurately capture the air interface, path loss and shadow fading effects. The SINR value is calculated as given in equation (7) on each channel in the simulated link. Then the data rate of the channel was calculated from the power assigned to the channel and the calculated SINR value. To assess the handover dormancy and service interruption time, \( T_{measure}, T_{signal}, T_{BS\_proc}, \) and \( T_{TRS\_proc} \) are thought to be 5 msec in light of the fact that a normal edge size of an IEEE 802.16e framework is 5 msec. \( T_{rng} \) and \( T_{assoc} \) are thought to be 20 msec and 50 msec, separately. The estimation of \( T_{assoc} \) is moderately extensive in light of the fact that it requires extra spine organize correspondence.
Table 2. Simulation parameters.

| S.No. | Simulation parameter | Values |
|-------|----------------------|--------|
| 1.    | Cell                 | 19 cells (6 Directional Antennas sectors), Carrier frequency 1.9GHz. |
| 2.    | Carrier frequency    | 1.9GHz |
| 3.    | BS Power constraint  | 30 dB  |
| 4.    | RS Power constraint  | 20dB   |
| 5.    | Cell radius          | 1km    |
| 6.    | In MCN 1 difference between a BS and an RS | 800 m  |
| 7.    | T measure            | 5ms    |
| 8.    | T_mueg_Bs and T_mueg_RS | 22ms |
| 9.    | T Biz                | 50ms   |
| 10.   | TBS_proc and TRS_proc | 5ms |
| 11.   | T signaling          | 5ms    |
| 12.   | Neighbours_Bs in SCN, MCN1 and MCN2 | 4 |
| 13.   | Neighbours_Bs in SCN | 1      |
| 14.   | Neighbours_Bs in SCN MCN 1 | 6 |
| 15.   | Neighbours RS in MCN 2 | 5 |

Figure 4 demonstrates the channel information rate and the comparing complete number of client supplies. The information indistinguishable for each channel since each channel is having diverse estimation of bearer recurrence, proliferation steady and way misfortune type. Impedance and clamors happening in cell systems are the fundamental purpose behind doing this examination. The obstruction happening in each channel was figured as given in condition (7) and (8). In the 19 cell arrangement of multihop cell systems, given in figure 1, radio signs proliferated from every phone is going about as a wellspring of impedance for the radio signs engendered from different cells.

![Figure 4. Channel data rate versus number of user equipment’s.](image)
Figure 5. Sector throughput with different user distribution.

Figure 6. Interference in a cell due to neighbour cells.

Figure 7. Channel frequency versus Interference.
Figure 5. shows the sector throughput comparison for ORAA-CN, 1x3x1-CN, 1x3x3-CN, NFR-CN, IC-CN, ORAA-MCN, 1x3x1-MCN, 1x3x3-MCN, NFR-MCN, IC-MCN. The LLM technique is having the sector throughput in the range of 12Mbps compared with other. The LLM uses the overloaded situation ($\rho=60$), of the sector throughput can increases with the handover conditions can be satisfied. The higher ratio greater 70 increases the handover conditions can be satisfied. The sector throughput will continue to rise until the conditions for the handover are not met.

![Graph showing SINR versus Channel power.](image1)

**Figure 8.** Channel SNIR versus Channel power.

![Graph showing Load Balance with handover interference.](image2)

**Figure 9.** Load Balance with handover interference.

The interference in each cell due to the signals propagated from other cells calculated using equation (7) and (8). Figure 6 shows the calculated interference in each cell due to the neighboring cell.

**6. Conclusion**

The main concept behind this work is long term and short term fading and varies with respect to the channel frequency. We modelled the large scale path loss and shadowing factor, and identified the effect of channel frequency. Figure 7 shows the effect of channel frequency on interference. The allocated power as per equation (9), (10) and (11) decides the interference on each channel. The power allocated to the channels did not affect the channel SINR value in high level as displayed in Figure 8. The Figure
9 shows the how load balancing and mobile station Handovering. It is used by both foundations and EU algorithms to interact with and balance load. This article gives users a load balance algorithm to offer a smooth service and thus improve the quality of service critical communication (QoS).

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