Load balancing over redundant wireless sensor networks based on diffluent

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Abstract

As the traffic blocking probability of traditional hard load balancing algorithms is generally high over redundant wireless sensor networks, This paper proposes a load balancing algorithm based on dividing the packet flow (LBD) over redundant wireless sensor networks based on the idea of soft load balancing. In the scheme, through numerical analysis, obtain the optimal flow-dividing ratio to determine the volume of traffic delivered to each network, which maintains network load balance. From the theoretical and simulative perspectives, the paper analyses the performance parameters, and the analytical results show that the performance of the scheme is better than other schemes. Simulation results show that the proposed method outperforms traditional hard load balancing techniques in terms of traffic blocking and packet loss probabilities.

Keywords: redundant wireless sensor networks, load balancing, packet flow diversion, access selection, handover

1 Introduction

The future of communication network is a redundant structure system, various wireless access network access to public core network based on all IP through a variety of different access technology [1]. Redundant wireless sensor network resource management technology, especially the load balance technology, is one of the key technologies to realize integration in the redundant wireless network, and is a research hotspot in recent years. Load balancing is the important method to implement effective resource sharing in the redundant wireless network, which can improve the utilization of wireless resources in redundant wireless networks, expand the system capacity, to provide users with better service.

References [2, 3] consider system load affected by the users, the condition of channel, the QoS (quality of service) requirements of business, and other factors, and put forward when the system load is greater than the prescribed threshold method, the high load transfer part of the user in the system to the low load system.

In reference [4] calculate the need of resources consumed by users access each network, the design target of access is. After the user access network, the ratio of consumption of resources and network resources available to is the minimum; reference [5] used multi-objective decision-making method for network selection in the redundant wireless network. Discuss the load balance and other parameters of compromise; in a redundant and distributed grid environment reference [6] designed a kind of immune clone task scheduling algorithm, to achieve the balanced allocation of resource and efficient scheduling tasks. The above references about method of load balancing are all hard load balancing - The user's business at the same time can only access a network, not well QoS guarantee business, business blocking ratio is higher [7]. References [7, 8] propose the concept of soft load balance. The packet of down link can be divided into sub stream, each child flows into the different wireless access networks, this method can more fully use of resources in the redundant wireless network. But references [7] only studied the best diversion ratio in specific network topology circumstances, not universal; and reference [8] only studied the diversion ratio under optimal wireless channel environment, the results deviation with the actual situation.

Aiming at the existing problem of the load balance method, This article propose the load balancing algorithm under the whole cover network environment based on packet flow diversion (load Balancing algorithm –based on dividing packet flow, LBD). Algorithm considered the effect of multipath and path loss, user service in redundant wireless network is obtained by numerical analysis of the optimal split ratio. When users need to access network, or switch, system downstream business will be divided into the subflows according to the optimal split ratio and the subflow will access or switch to the corresponding network, to improve the network capacity, improve the system performance.

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2 The system model

2.1 SOFT LOAD BALANCE NETWORK STRUCTURE

In this paper, on the basis of reference [9], improved a layered half centralized network structure as shown in Figure 1. Several location adjacent area mapping into a basic grid, information server-IS, resources allocation-RA, and resources statistics-RS are collectively referred to as resource management unit-RMU, it is responsible for the management of grid resources. RS is set to access node, in the node for statistics and calculation of the resource information; RA is used to collect the RS information, and according to the situation of the node load and basic grid resources for load balancing. IS as RA supervisor server, basic grid structure under the normal state only responsible for edges of resource allocation and the identification of the storage nodes, the information such as position, load condition, but when the management of RA malfunction can't work, IS can quickly take over and perform the function of RA.

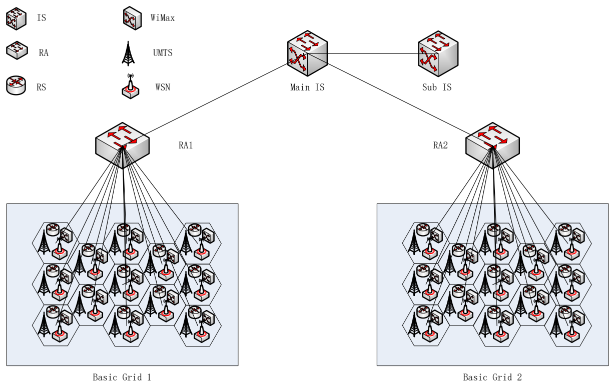

FIGURE 1 Hierarchical semi-centralized architecture in a two-dimensional resource unit can get the biggest transfer rate.

In order to support the soft load balancing. The public link layer are introduced to processing access control signals in RA [7]. In each of the access network, below the public link layer is the media access control layer and physical layer, the MAC layer is located in the RS. Each MAC protocols report it channel state to the public link layer, Public link layer determine the size of the diversion ratio according to the obtained channel condition and system load conditions. The public link layer data received from the MAC layer, according to the data of the serial number on the reorder, and then to transfer the data through the network layer to the transport layer.

2.2 TWO-DIMENSIONAL RESOURCE UNIT

System model have M kinds of overlapping coverage of access system, different access system adopts OFDM (orthogonal frequency division multiplexing) technology. For system m ($m \in 1, 2,\dots, M$), all subcarrier in sequential mode can be divided into a number of sub-channels. Each channel contains F_m carrier. The frame length T_{fm} is divided into isometric time slot, a time slot contains S_m OFDM symbols. Such a time slot on the time domain and frequency domain on a child channel will constitute a two-dimensional resource unit, as the basic unit of the resource allocation in OFDM system [4].

In a two-dimensional resource unit can get the biggest transfer rate:

$$b_{i,m} = \frac{F_m S_m C_{i,m}}{T_{f,m}}, \quad (1)$$

where after the user i access system m. Based on adaptive coded modulation mechanism to determine the information bits $C_{i,m}$ carried by each modulation symbols [10].

2.3 CHANNEL MODEL

Considering the influence of multipath and path loss, channel model of this paper by using the Rayleigh fading model, the user receives the base station signal power [4]:

$$P_R = \alpha^2 A d^{-\beta} P_T, \quad (2)$$

where P_T for the access point transmission power. In this paper, redundant wireless sensor networks in each system, assuming that access point transmission power is constant, and evenly distributed in the entire history of the available frequency band; α is the mean of 1 and obey exponential distribution of random variables, used to characterize the fast fading. $Ad^{-\beta}$ is used to represent the path loss, constant A decided by the antenna height and carrier frequency, β is attenuation index, d is the distance between the user and the access point.

Assume that the user i in the system m within the coverage of the j access point, the dry ratio $\gamma_{i,m,j}$ at the receiving end can be expressed as:

$$\gamma_{i,m,j} = \frac{\alpha^2 A d_{i,m,j}^{-\beta} P_{T,m}}{\sum_{k=1}^{N_m} \alpha^2 A d_{i,m,j}^{-\beta} P_{T,m} + \omega_{i,m}}, \quad (3)$$

where, $\omega_{i,m}$ is the noise power at the receiving end of user i in the system m, $d_{i,m,j}$ is the distance between user i and the j access point of system m, N_m is the number of other access points which are the disturbance of access point j of system m, $P_{T,m}$ is the transmission power of access points in the system m.

In the AWGN channel with M - QAM modulation the biggest transport bit error rate from the access point to the user i in the system m [4] is:

$$P_{BER,i,m} = \frac{1}{5} e^{-\frac{1.5\gamma_{i,m,j}}{2^{C_{i,m}-1}}}. \quad (4)$$

When the packet length is K bits, in order to obtain the relationship between the packet loss rate and bit error rate, considering the limiting cases. Assume that after through other error correction mechanism, any one bit error means that the entire packet transmission error, the packet loss rate of the user i in the system m is [11]:

$$P_{PL,i.m} = 1-\left(1-P_{BER,i,m}\right)^{K} . \quad (5)$$

Considering automatic retransmission mechanism of MAC layer, an average transfer numbers of receiving a right packet group took [4]:

$$K_{i,m} = \frac{1}{1-P_{PL,i,m}} . \quad (6)$$

3 The load balancing algorithm based on packet flow diversion

When the user have some group business need network access, or in the process of service because of in the system or between the system switch due to mobile, factors such as the decrease of the quality of the business requirements, System for its first calculated optimal split ratio, then according to the optimal split ratio to access or switch to the appropriate network, the algorithm overall process is shown in Figure 2, algorithm steps as shown in section 2.3.

3.1 TWO-DIMENSIONAL RESOURCE UNIT ALLOCATION MODEL

Assume the rate demand of user i is R_i, user i business in system m transmission rate is $R_{i,m}$, the diversion ratio of users i in the system m is $\omega_{i,m}$, the Equations (7) and (8) are as follows:

$$R_{i,m} = R_i \omega_{i,m} , \quad (7)$$

$$\sum_{m} \omega_{i,m} = 1 , \quad (8)$$

After user i access system m, each frame required two-dimensional resources unit for an average is:

$$n_{i,m} = \left\lceil k_{i,m} \frac{R_{i,m}}{b_{i,\mathrm{m}}} \right\rceil , \quad (9)$$

where, $\lceil x \rceil$ is the minimum integer greater than or equal to x.

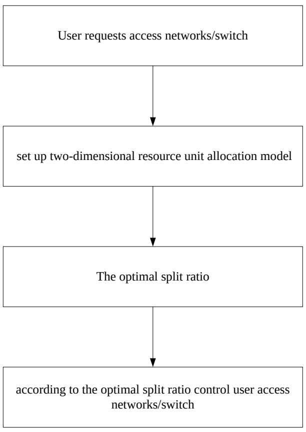

FIGURE 2 Flow chart of LBD

Assume that the user i access system m before the j access point, the access point is covered inside the village which have accessed $I_{m,j,I}$ users, the load in the location can be expressed as:

$$L_{m,j,i} = \sum_{k-1}^{I_{m,j,i}} n_{k,m} . \quad (10)$$

In order to satisfy the QoS requirements of group business, this paper adopts the following strategies:

1) The average service rate of the non real-time business is greater than the minimum service rate, on the basis of using the best scheduling mechanism. So in access to choose, Equation (9) can be said it took an average of network resources.

2) Most of the grouped data real-time business to send in a maximum time delay constraint. This paper adopts the effective bandwidth theory to ensure real-time QoS requirements of the business, If the bandwidth of the network to provide real-time business is greater than the effective bandwidth, its QoS guaranteed [12]. Assume that grouping package (on) the activation state only at fixed intervals, and in the inactive state (off) does not produce. Suppose system m on his stay on and off states respectively obey negative exponential distribution of parameters for the λ_m and μ_m, the probability of packet delay is greater than the given threshold D to ε, the user i equivalent bandwidth of real-time business can be expressed as [13]:

$$W'_{i,m} = \frac{R_{i,m}(\mu_m D - \ln \varepsilon)}{(\lambda_m + \mu_m)D - \ln \varepsilon} . \quad (11)$$

If the network to provide real-time business available data rate is greater than the type of effective bandwidth value in Equation (11), the real-time business QoS can be guaranteed. By Equation (9), real-time business users i access system m 2d resources required for each frame after the average cell number is:

$$n'_{i,m} = \left\lceil k_{i,m} \frac{W'_{i,m}}{b_{i,\mathrm{m}}} \right\rceil . \quad (12)$$

3.2 THE BEST DIVERSION RATIO METHOD

This paper takes the real-time business as an example the optimal distribution ratio, real-time business best solution of the diversion ratio is similar.

Set up an access point in the system m available unit for a total of 2d resources $L_{T,m}$, define the user i to the influence degree of the network load after access networks (hereinafter referred to as the load factor) is:

$$\eta_i = \sum_{m=1}^{M} \frac{n_{i,m}}{L_{T.m}} . \quad (13)$$

In order to get the best load balancing effect, user i in the system m the best split ratio $\omega_{i,m}^{*}$ is obtained by Equation (14):

$$\left[\omega_{i,1}^{*},..,\omega_{i,M}^{*}\right]=\arg\min\eta_i=\arg\min\sum_{m=1}^{M}\frac{n_{i,m}}{L_{T,m}}. \quad (14)$$

Load factor expressions η_i is received using Equations (4), (5), (7), (9) and (13):

$$\eta_i\sum_{m=1}^{M}\frac{\left|B_{i,m}\omega_{i,m}\right|}{L_{T,m}}, \quad (15)$$

where:

$$B_{i,m}=\frac{R}{\left(1-P_{PL,i,m}\right)b_{i,m}}. \quad (16)$$

When the user i access networks m, R_i, $P_{PL,i,m}$ and $b_{i,m}$ are constant values, so $B_{i,m}$ for the fixed value.

Best diversion ratio of the calculation steps are as follows:

Step 1: when $l=\arg\min_{m\in\{1,\dots,m\}}\frac{B_{i,m}}{L_{T,m}}$, j access points of system l have enough resources to allow users i all access, when $L_{T,l}-L_{l,j,i}\geq B_{i,l}$, get the objective function for solutions of Equation (14):

$$\omega_{i,m}^{*}=\begin{cases}1, & l=\arg\min_{m\in\{1,\dots,m\}}\frac{B_{i,m}}{L_{T,m}} \\ 0, & other\end{cases}. \quad (17)$$

Step 2 when the j access point of system l does not have enough resources in to allow user i all access, when $L_{T,l}-L_{l,j,i}<B_{i,l}$, make $n_{i,l}=L_{T,l}-L_{l,j,i}$, you can get:

$$\omega_{i,m}^{*}=\frac{L_{T,l}-L_{l,j,i}}{B_{i,l}}, \quad l=\arg\min_{m\in\{1,\dots,m\}}\frac{B_{i,m}}{L_{T,m}} \quad (18)$$

make $l^{'}=\arg\min_{m\neq l,m\in\{1,\dots,m\}}\frac{B_{i,m}}{L_{T,m}}$, if the first j access points of the system l have enough resources to the user i full access, when $L_{T,l'}-L_{l',j,i}\geq\left(1-\omega_{i,l}^{*}\right)B_{i,l'}$, then:

$$\omega_{i,m}^{*}=\begin{cases}\frac{L_{T,l}-L_{l,j,i}}{B_{i,l}}, & l=\arg\min_{m\in\{1,\dots,m\}}\frac{B_{i,m}}{L_{T,m}} \\ 1-\omega_{i,l}^{*}, & l^{'}=\arg\min_{m\neq l,m\in\{1,\dots,m\}}\frac{B_{i,m}}{L_{T,m}} \\ 0, & other\end{cases}. \quad (19)$$

Step 3 when the sum of all the available resources in system l and $l^{'}$ cannot meet the demand of user business resources, $L_{T,l}-L_{l,j,i}<B_{i,l}$ and $L_{T,l'}-L_{l',j,i}<\left(1-\omega_{i,l}^{*}\right)B_{i,l'}$, similar to the step 2 calculation values other $\omega_{i,m}^{*}$ than $m=1$.

Step 4: if the sum of all system resources available cannot meet the demand of users i rate R_i, declined to the user's access to the switch or request.

3.3 LOAD BALANCING STEPS

LBD algorithm steps are as follows:

Step 1: when a user i need access to the network or switch, RA or IS (when user i on the verge of basic grid) scanning for the available access points list of users i.

Step 2: RS according to Equation (3) to measure Signal to Interference Ratio $\gamma_{i,m,j}$ from user i to each available access points. According to the Equations (4) and (5) channel bit error rate and packet loss rate are calculated respectively. Combined with the corresponding link adaptive mechanism with Equation (1) to calculate the corresponding each 2d resource unit can obtain the maximum transmission rate of $b_{i,m}$. To transfer the result of the measurement and calculation for RA.

Step 3: RA through using the method of section 2.2 to calculating optimum diversion ratio for the user i $\omega_{i,m}^{*}$.

Step 4: RA according to the optimal split ratio $\omega_{i,m}^{*}$, to divide users i business into sub stream, and flow or switch to the corresponding access to the network.

4 Algorithm performance analysis

4.1 THE SIMULATION ANALYSIS

Proposed by reference [4] MLB (maximum load balancing algorithm is hard load balancing method of superior performance of an algorithm, in order to verify the LBD algorithm performance, in this paper, the LBD algorithm and the MLB business traffic congestion, packet loss rate of the algorithm and the network load balancing degree has carried on the simulation analysis. The simulation scenario is shown in Figure 3 [4].

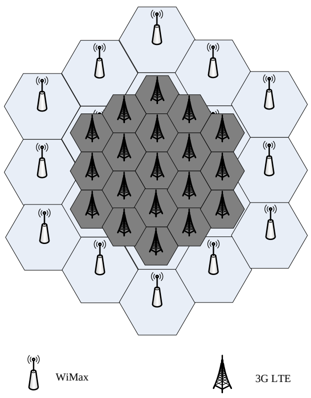

FIGURE 3 Simulation scenario

LTE system area (1.5 km) radius and WiMax system area (radius 3 km) overlapping coverage, two systems centre village access point location collocated. At the beginning of the simulation, the user random distribution in the region of the repeat coverage, random direction, moved to the village edge, handover will happen. When user move at speed 120 km/h, user's location and movement direction is updated once every 100 ms, one direction change ±45° at 0.2 probability at a time. Each user's business source are independent of each other, and with the same probability to generate real-time and non real-time business. Simulation parameter Settings as shown in Table 1.

TABLE 1 Simulation parameters settings

name	**UMTS**	**WIMAX**
Carrier frequency/bandwidth	2.0 GHz/10MHz	3.5GHz/10MHz
$T_{f,m}$	10 ms	10 ms
OFDM symbol cycle	0.2 ms	0.2 ms
NFFT	512	1024
$P_{T,m}$	43dBm	46dBm
$W_{i,m}$	-170 dBm/Hz	-174 dBm/Hz
Two dimensional resource unit	24 consecutive subcarrier and 10 symbols of cycle	24 consecutive subcarrier and 10 symbols of cycle
K	512 bit	512 bit
Real-time business rate	Uniform distribution in [50 kb/s, 200 kb/s]	Uniform distribution in [50 kb/s, 200 kb/s]
Non real-time business rate	Uniform distribution in [40 kb/s, 140 kb/s]	Uniform distribution in [40 kb/s, 140 kb/s]
λ_m/μ_m	2.84 s/1.53 s	2.84 s/1.53 s
Business generate time interval	Obey the average poisson distribution for 1 s	Obey the average poisson distribution for 1 s
Business last time interval	Obey the average poisson distribution for 2 s	Obey the average poisson distribution for 2 s
name	UMTS	WIMAX
Carrier frequency/bandwidth	2.0 GHz/10MHz	3.5GHz/10MHz

The statistical simulation results, statistics only two network repeat coverage areas darker areas in (Figure 3). According to the parameters of Table 1, Through the Matlab simulation results as shown in Figure 4 ~ 7, users in the figure is a LTE area within the scope of active users.

Figure 4 for the number of IP when using the algorithm of LBD shunt and the ratio of total access and switching times. When users less than 30, have enough resources to accept user network, so packet flow without shunt. With the increase of number of users, a single network resources began to can't satisfy user needs of the business, user packet of the business flow is divided into two sub flow access two network at the same time.

Figure 5 for the network load is full cause user blocking probability. Due to network users, less than 30 have enough resources to acceptance of users, users under two kinds of algorithm the block probability is 0. With the increase of users, the user's block probability, LBD algorithm can be very high in both the network load will users business packet flow is divided into two sub flow access two network at the same time, so its block probability MLB was always lower than the algorithm, and the more users, the more obvious advantages in block probability LBD algorithm.

Figure 6 for the user to access the network or when switching the average packet loss rate. It can be seen that with the increase of users, the LBD algorithm proposed in this paper, the packet loss rate than MLB always low packet loss rate of the algorithm.

Figure 7 for two networks under two kinds of algorithm compares the average normalized load, two algorithms is visible in the aspect of load balance ability, has been close to two network load conditions.

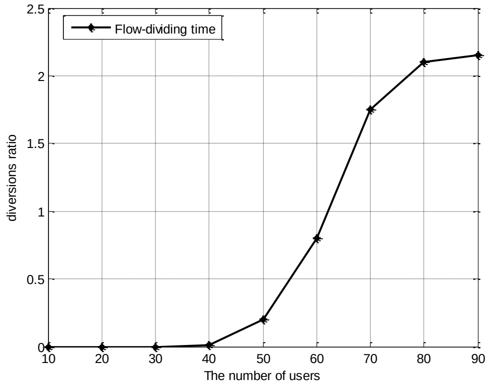

FIGURE 4 Flow-dividing time.

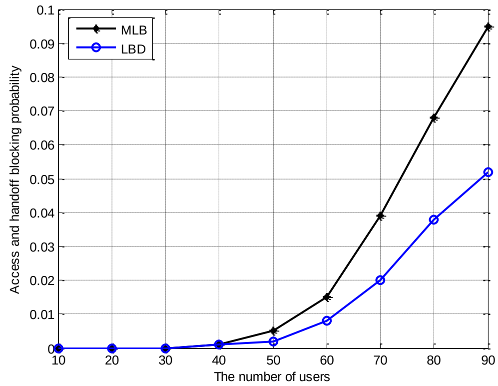

FIGURE 5 Blocking probability.

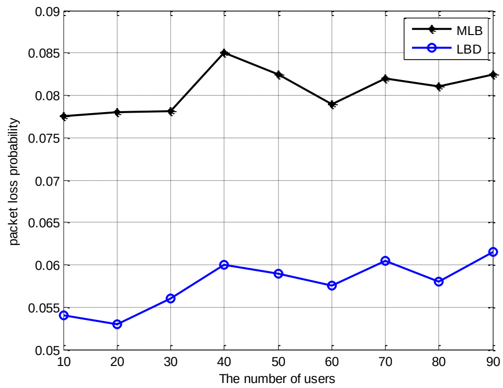

FIGURE 6 Packet loss probability.

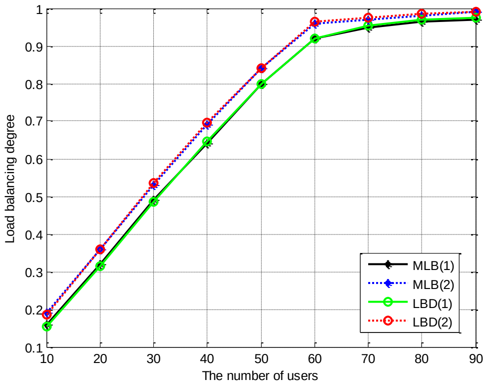

FIGURE 7 Load balancing degree.

4.2 ALGORITHM APPLICABILITY

Reference [7] study the network structure of two kinds of system coverage crisscross overlap, neighbourhood radius of two systems, the same access point located at the centre of the community, and a system of community centre is located in another system on the edge of the neighbourhood, see Figure 3 in reference [7]; In this paper, we study the network structure as the centre of community access point phase coincidence of the two systems, and neighbourhood radius of two systems can be different, this structure is closer to the actual network. Reference [7] only analyses the two systems centre village access point best in the middle of the diversion ratio; Algorithm in this paper to consider all the best shunting overlapping coverage ratio, scope of application is more widely. Reference [8] only studied the ideal of the wireless channel environment load balance; In this paper, considering the influence of multipath and path loss. Therefore, compared with the existing soft load balancing algorithm, this algorithm is more universal.

5 Conclusions

In this paper, based on packet flow diversion of heterogeneous wireless network load balancing algorithm. Algorithm considering the whole network environment, the real-time statistics network status indicators, calculated under different network load balancing target users access to the network or the best split ratio when switching. Choose according to optimal split ratio for access or switch, can achieve less resource consumption, improve the system capacity. The simulation results show that LBD algorithm can effectively balance the network load, and the group business average blocking probability and packet loss spontaneously in a relatively traditional MLB algorithm has obvious improvement.

Acknowledgments

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