Design of Optimization Algorithm for WLAN AP Selection during Emergency Situations

Maneesha V. Ramesh
AMRITA Center for Wireless Networks and Application,
Amrita Vishwa Vidyapeetham (AMRITA University),
Kollam, India
maneesha@am.amrita.edu

Nisha M. S.
AMRITA Center for Wireless Networks and Application,
Amrita Vishwa Vidyapeetham (AMRITA University),
Kollam, India
nisha_ms87@yahoo.com

***Abstract*— WLAN is now widely used for emergency purposes because of its fast deployment capability. Efficient and intelligent arrangement and selection of access points (AP) are very crucial in emergency situations. Coverage and capacity are two central problems faced when APs are placed in a disaster scene. The paper proposes a power efficient algorithm for AP selection in emergency situations. The current AP selection algorithm only considers received signal strength, and this algorithm arise problems like overloading in APs, congestion and power wastage in networks. But the proposed Dynamic Load Balancing Fairness Algorithm (DLBFA) overcomes all these problems by using a new selection score, obtained by optimizing channel throughput and voice quality. Apart of this score the number of nodes connected to an AP and RSSI are also considered. The main advantage of DLBA is that it can work on both data and voice applications.**

Keywords-Access Point (AP) selection, Wi-Fi, optimization, greedy algorithm, VoWi-Fi.

I. INTRODUCTION

Recent years a tremendous increase is shown in the popularity of IEEE 802.11 Wireless Local Area Network (WLAN) – generally referred by Wi-Fi network. And the immense increase in the usage of Voice over Wi-Fi (VoWi-Fi) leads to use the Wi-Fi networks for emergency communication. The ability of quick setting up, low cost and portability makes the Wi-Fi network capable for building a temporary communication network. Infrastructure based Wi-Fi networks consists of Access Points (AP) and each nodes connected to any one of AP for communication. Figure 1 Shows network architecture of emergency communication system using infrastructure Wi-Fi. Figure shows some communication devices and APs. Sender node contacts corresponding AP and that AP link to the other APs corresponding to the receiving node and transfer data. The dotted arrows show an example communication path between sender and receiver. We can easily set up this kind of network soon after the disaster. The advantages of these kinds of network are, they are very easy to implement and we can use smart phones, laptops etc as communication devices. But we should take care of the energy constraints of the equipment.

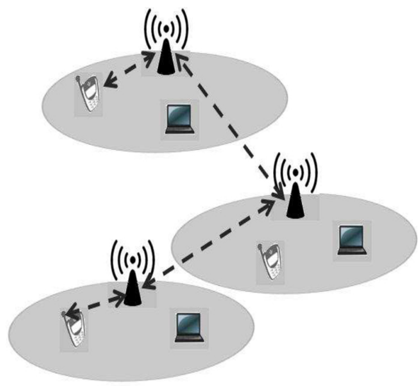

Figure 1: Network design for emergency communication for VoWi-Fi

Most popular and widely used IEEE 802.11 protocols are 802.11b and 802.11g (both using 2.4 GHz ISM band). 802.11b and 802.11g divides 2.4 GHz band into 13 channels each of with 22 MHz. Since the spacing between each channel is only 5 MHz, AP can operate only on three channels without interference, as shown in figure 2.[1]. Therefore the introduction of a fourth AP will results in interference.

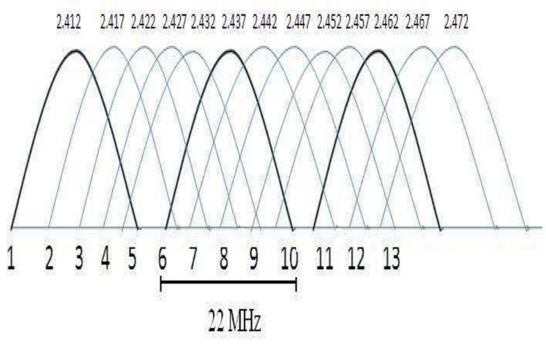

Figure 2: IEEE 802.11 channel assignment

978-1-61284-486-2/11/$26.00 ©2011 IEEE

Factors like number of stations connected to AP, throughput of AP, error rate etc. are badly effect the performance of a network. Since VoWi-Fi services are interactive real time applications, they need high QOS and low packet error rate. The widely accepted AP selection algorithm based on received signal strength indicator (RSSI) selects AP with high RSSI. This algorithm probably results in assigning one AP with more number of nodes and thereby causes load imbalance, congestion and voice quality degradation in the network.

The proposed system designs a Dynamic Load Balancing Fairness Algorithm (DLBFA) for AP selection in WLAN emergency networks. We introduce a new metric for voice application in WLAN AP selection procedure. Apart of this metric, the number of nodes connected to an AP and RSSI are also considered. The algorithm aims to get lower power consumption of nodes, high voice quality and QOS.

The rest of the paper is arranged as follows. Section 2 describes related work in access point selection algorithms. Section 3 describes the system modeling for the proposed algorithm. Section 4 describes about the design of DLBFA. Finally conclude in section 5.

II. Related Works

In [2], authors propose a decentralized algorithm for AP selection, which considers the number of nodes connected to one stations. Their algorithm, known as Maximizing Local Throughput (MLT), maximizes the total throughput and selects AP with maximum throughput.

In [4], the authors propose to use multiple criteria for selecting AP. Their criteria are number of nodes connected to same AP, distance and a score based on an amount of real time traffic load. The simulation results in [4] shows that their algorithm achieves improved voice capacity.

In [6], the authors designed a new metric, which is based on the throughput and impact of high rate nodes to the network, for selecting an AP. The results in [6] shows that the system achieves better user Quality Of Service (QOS) and better utilization of resources.

III. System Model for IEEE 802.11 based Emergency communication Networks

Selecting As depicted in figure 1, the system model for emergency communication consists of several nodes and APs using IEEE 802.11 radio. Since there are several APs interference would be there between these APs. Two important factors to be considered when placing APs are coverage and throughput [5].

The system model for emergency situation consists of only less number of APs. And our AP selection algorithm should be capable of obtaining higher throughput and lower power consumption. For achieving the above mentioned criteria, we propose to use some new criteria. The new criteria for AP selection are:

1. Voice quality (calculated with the help of R-factor)
2. Number of nodes connected to an AP
3. Overall throughput
4. RSSI

We assume that there are m number of nodes and k number of APs in our system model. Let $N = \{n_1, n_2, n_{3,}, \ldots., n_m\}$ denote the set of nodes in the network and $A = \{a_1, a_2, a_{3,}, \ldots., a_k\}$ denote the set of APs in the network.

In the IEEE 802.11 standard, it is defined that, each node should be connected to any one of the AP in order to accomplish communication. Two methods are discussed in [1] for associating a node with AP. When a new node is come, to be associated with the AP, a node should get synchronization information from an AP. Scanning process is used for obtaining synchronization information. Since power is a crucial factor, active scanning is preferred. In active scanning nodes sent probe request for finding available APs. After this process an authentication process and association process is executed. Only after association process a node can start communication. The notation $c_{ij} = 1$ meant that node n_i is associated to AP a_j. The set $C = \{a_i |\ a_i \epsilon A\}$ denotes the candidate set of APs.

IV. Dynamic Load Balancing Fairness Algorithm (DLBFA).

We aim to optimize the AP selection problem here. For optimizing AP selection, greedy algorithms are used. Greedy algorithm is a type of optimization problem works in different phases. The main idea behind greedy algorithm is that they find local optimal solutions in each phase independent of the future conditions and at the end it selects the global optimal solution.

Communication in emergency situation may include both data and voice. The throughput of network is different in the both cases. Therefore, in order to maximize the throughput of the network we should consider normal communication and VoWi-Fi communication separately.

For obtaining an efficient AP selection algorithm for emergency situations, the authors proposes a new metric for VoWi-Fi services based on the overall throughput of each AP denoted by $\mathbf{\Gamma_{data}}$ and $\mathbf{\Gamma_{voice}}$, where $\mathbf{\Gamma_{data}}$ is denoted by the throughput of an AP when data communication is takes place and where $\mathbf{\Gamma_{voice}}$ is denoted by the throughput of an AP when VoWi-Fi communication is takes place.

Our proposed algorithm first selects a candidate set C with available APs. In the second step according to the new metric $\boldsymbol{\Gamma}$ a set of APs are selected. In the third step according to the number of nodes connected to each AP, the set C is again short listed. At the final step the P with maximum RSSI is selected.

For formulating the metric for maximizing throughput and QOS of selected AP, we use two factors:

1. The throughput of the AP
2. Voice quality of the channel

We have the equation for time taken, T_t to transmit a data or voice of bits from [1] as,

$$T_{t=}\ T_{RTS} + T_{CTS} + (T_{Data} Or\ T_{Voice}) + T_{ACK} + \quad T_{DIFS} + 3T_{SIFS} \quad (1)$$

Where $T_{RTS}, T_{CTS}, T_{Data}, T_{Voice} and\ T_{ACK}$ are times taken to send a Request To Send (RTS) , Clear To Send (CTS), data packet, voice packet and acknowledgement packet respectively and $T_{DIFS}\ and\ T_{SIFS}$ are the lengths of Distributed Inter Frame Space (DIFS) and Short Inter Frame Space (SIFS).

The throughput, $\boldsymbol{\Gamma}$ can be derived from the formula

$$\boldsymbol{\Gamma} = \frac{Data}{Time\ taken\ for\ a\ successfull\ transmission} \quad (2)$$

By assuming the all that packet are of same size, we can obtain a linear relation for $\boldsymbol{\Gamma}$ from [2].

$$\boldsymbol{\Gamma} = \Lambda_{data} = \frac{1-P_e}{N} \quad (3)$$

Where P_e is the packet error rate in the wireless link, and N is the number of nodes currently connected to the AP. If the application is not VoWi-Fi we can use $\boldsymbol{\Gamma}$ as the new metric for AP selection. We can denote the new metric as Λ_{data}. The value of Λ_{data} ranges between zero and one, i.e.

$$0 \leq \Lambda_{data} \leq 1 \quad (4)$$

If the application is VoWi-Fi the metric should be consider the voice quality also. For determining the voice quality, ITU recommendation G.107 introduced R-factor [7].

$$R = SNR - I_S - I_d - I_e + A \quad (5)$$

Where R is the R-factor, SNR is the signal to noise ratio (SNR), I_S is the amplitude of the signal, I_d is the impairments caused by delay, I_e is impairments caused by low bit rate codec and A is the advantage factor. Usually R-Factor ranges between 70 and 90 are used by many networks. Table 1 listed the user opinion based on different values of R-Factor.

TABLE 1: User opinion based on different values of R-Factor.

User Opinion	**R-Factor**
Very Satisfied	90-100
Satisfied	80-90
Some Users Satisfied	70-80
Many Users Dissatisfied	60-70
Nearly All Users Dissatisfied	50-60
Not Recommended	0-50

Now Λ_{data} , the AP selection metric for VoWi-Fi applications can be formulated as,

$$\Lambda_{voice} = \left(\frac{1-P_e}{N}\right)\frac{R}{R_{max}} \quad (6)$$

Where R_{max} is the maximum R-Factor value, equal to hundred. The value of Λ_{voice} ranges between zero and one, i.e.

$$0 \leq \Lambda_{voice} \leq 1 \quad (7)$$

Using these criterions, the DLBF algorithm can be described as follows:

Step 1: A candidate list $C = \{a_i | \ a_i \epsilon A\}$ is prepared for the new node based on the arrival of beacon frames.

Step 2: If the application is VoWi-Fi calculate Λ_{voice} using equation (7) or else calculate Λ_{data} using equation (3). Form an optimal intermediate solution set based on Λ. If there is only one AP in the optimal set, select that AP as the solution. Otherwise go to next step.

Step 3: From the intermediate solution obtained from step 2, calculate the number of nodes associated with each AP, and make an optimal intermediate solution with APs having minimum number of nodes connected. If there is only one AP in the optimal set, select that AP as the solution. Otherwise go to next step.

Step 4: From the intermediate solution obtained from step 3, calculate the number RSSI of each AP, and select the AP with maximum RSSI. The selected AP will be the optimal

AP, which offers high QOS, load balancing and better voice quality for the connection.

The flow chart of the algorithm is shown in figure 3. Pseudo code for DLBF algorithm for each node n_i is shown below:

1) *Calculate* $C = \{a_j \mid n_i\ receives\ beacon\ frame\ from\ a_j,\ 0 \leq j \leq k\}$

2) *For each AP* $a_j \epsilon C$
   a) *If application is VoWi-Fi, calculate* $\Lambda_{voice} = \left(\frac{1-P_e}{N}\right)\frac{R}{R_{max}}$ *Or else*

   Calculate, $\Lambda_{data} = \frac{1-P_e}{N}$

   b) *Form* $C_{inter} = \{a_j \mid \Lambda\ is\ desirable,\ a_j \epsilon C\}$

   b) *if* $|C_{inter}| == 1$, *select* $a_j \epsilon C_{inter}$ *as the optimal solution. Or else go to next step.*

3)
   a) *For each AP* $a_j \epsilon C_{inter}$, *calculate* $N_j = number\ of\ nodes\ associated\ to\ each\ a_j,\ a_j \epsilon C_{inter}$

   b) *Form* $C_{opt} = \{a_j \mid N_j\ is\ desirable,\ a_j \epsilon C_{inter}\}$

   c) *if* $|C_{opt}| == 1$, *select* $a_j \epsilon C_{opt}$ *as the optimal solution. Or else go to next step.*

4)
   a) *For each AP* $a_j \epsilon C_{opt}$, *calculate* RSS_j

   b) *Select AP* a_j *such that* $RSS_j = max\{RSS_j \mid a_j \epsilon C_{inter}\}$

Algorithm 1: DLBF algorithm for AP selection

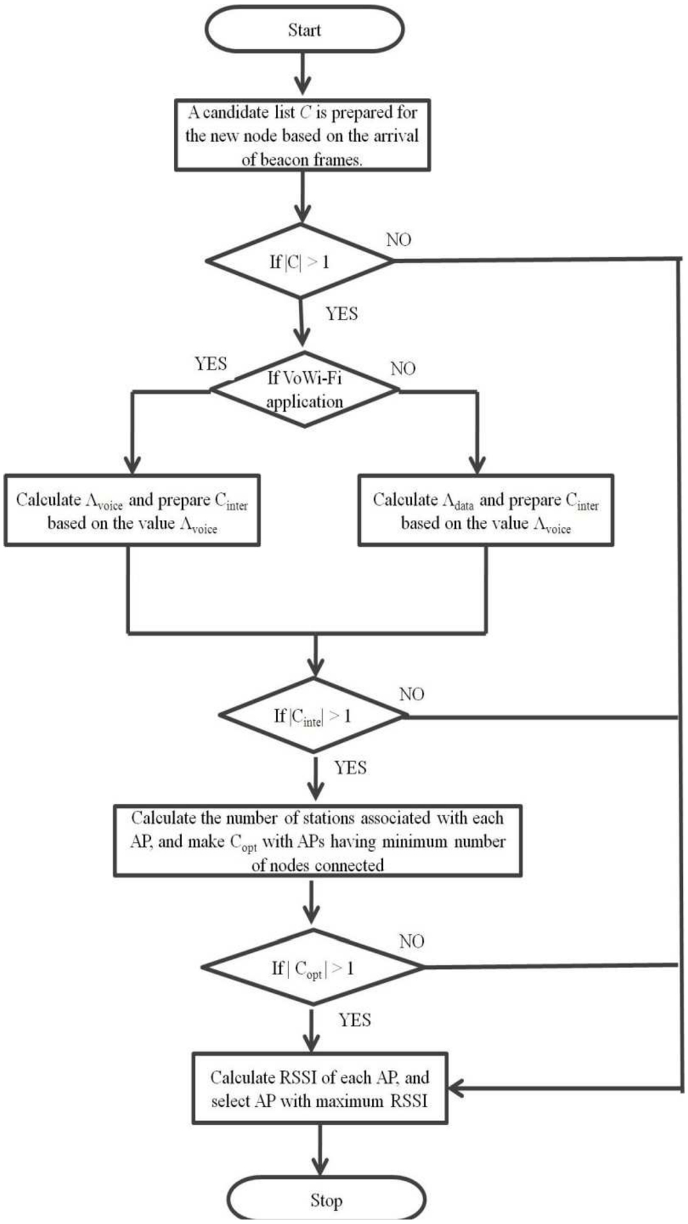

Figure 3: Flow chart of DLBF algorithm

V. SIMULATION MODEL AND PERFORMANCE ANALYSIS

The proposed algorithm is implemented by C language. The RSSI value between each node and AP is generated randomly using a random number generator. The performance of our algorithm is compared with the traditional RSSI based algorithm and R-factor based algorithm. The scenario consists of three APs and varying number of nodes.

In the simulation model we compare the load balancing capability of our algorithm, RSSI based algorithm and the

R-factor based algorithm. Figure 4. Shows the result obtained by the simulation. The variation of number of nodes connected to each AP is high in the RSSI based algorithm. The R-factor based algorithm shows better performance in lesser number of nodes. When the number of nodes increases variation of number of nodes connected to each AP is tremendously increases in both RSSI based algorithm and R-factor based algorithm. We can see from the figure that the proposed DLBF algorithm has a constant variation in all situations. So the DLBFA can perform much better than the other algorithms in all situations. And also it can save energy by better load balancing of APs.

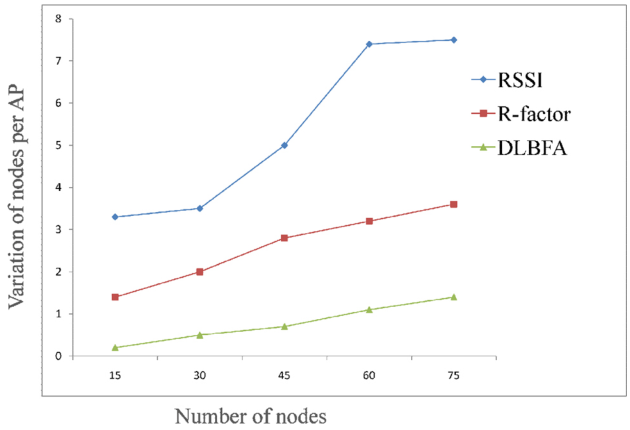

Figure 4: Simulation result

VI. CONCLUSION

AP selection algorithms are very crucial in WLAN based emergency communication networks. In the present paper we propose a dynamic AP selection algorithm suitable for emergency communication. The DLBF algorithm proposes more better AP selection than the conventional RSSI based AP selection. The proposed algorithm calculates a new selection metric for voice applications. The more important advantage of the algorithm is that it works for both data and voice applications. The selection criterion is different for both applications. The proposed DLBF algorithm dynamically changes the selection criterion suitable for both applications. The algorithm also considers number of nodes connected to an AP and RSSI, thereby assures minimum power usage, load balancing and good voice quality.

As a future work we will do AP selection algorithm for multi rate WLANs.

REFERENCES

[1]. IEEE, "Information technology - Telecommunications and information exchange between systems - Local and metropolitan area network-Specific requirements - Pan 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: IEEE 2007 .

[2]. Y. Fukuda, T. Abe, and Y. Oie. Decentralized access point for wireless LANs. In Proceedings of Wireless Telecommunications Symposium, 2004

[3]. Akihiro Fujiwara, Yasuhiro Sagara and Masahiko Nakamura, “Access point selection algorithms for maximizing throughputs in wireless LAN environment.” International Conference on Parallel and Distributed Systems , Volume 2, pp.1 – 8, Dec. 2007

[4]. Yasufumi Morioka, Takeshi Higashino, Katsutoshi Tsukamoto and Shozo Komaki. “AP Selection Algorithm for VoIP Services in Mixed Traffic WLAN Environment.” 1st. IFIP Wireless Days Conference, pp-1-8, Dec 2008

[5]. Robert Akl and Sangtae Park, “Optimal Access Point Selection and Traffic Allocation in IEEE 802.11 Networks” on proceedings of 9th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI'05), 2005.

[6]. Murad Abusubaih, Sven Wiethoelter, James Gross and Adam Wolisz, “A new access point selection policy for multi-rate IEEE 802.11 WLANs” International Journal of Parallel, Emergent and Distributed Systems Vol. 23, No. 4, pp. 1-20, August 2008.

[7]. ITU-T Recommendation G.107, “The E-Model, a computational model for use in transmission planning” Dec-1998.