Integrated WiFi/WiMAX Heterogeneous Wireless Network with Minimum Cost Flow Robust Optimization Uncertain Demand Problem

Hla Myo Tun,and Aye Thandar Phyo

Abstract— **The next generation wireless communications systems are envisioned to integrate multiple wireless access technologies (i.e., IEEE 802.11-based WiFi WLAN and IEEE 802.16-based WiMAX WMAN) to provide high-speed communications services to mobile users in a seamless manner. In such a heterogeneous wireless network, the users are able to access different wireless networks according to their preference, performance and cost. In this research, the radio resource management for this integrated heterogeneous wireless network will be proposed. At the mobile terminal, network selection algorithm will be developed to make the decision of connection (either WiFi or WiMAX or both) so that the QoS requirements are satisfied while the connection cost is minimized. An optimization problem will be formulated and solved for an optimal decision. In addition, the applications of this integrated heterogeneous wireless networks in vehicular network and e-Health will be explored.**

Index Terms—**minimum channel gain flow, heterogeneous network, robust optimization, minimum cost flow problem, WiFi/WiMAX .**

I. INTRODUCTION

Future wireless access networks are expected to consist of multiple radio access standards and base station technologies shaping what is called as heterogeneous networks [1, 2]. This is because the use of consecutive productions of radio access standards lean to overlap significantly, and no single technology has proven to be suitable and reasonable for all services and consumption circumstances. More purposely, heterogeneous networks in this framework pass on to both multi access networks, where multiple radio access technologies based on diverse standards are admittance with a multi radio competent terminal and hierarchical cell structures comprised of a single radio access standard with diverse base station modules.

While mobile systems proffer high-quality coverage and

Dr. Hla Myo Tun, Department of Electronic Engineering, Mandalay Technological University, No(3/29), Nawaday Garden, Hlaing Thar Yar Township, Yangon , Myanmar, hmyotun@myanmar.com.mm

Ma Aye Thandar Phyo, School of Computer Engineering, Nanyang Technological University, Singapore, ayethandarphyo@gmail.com

reliability for low and reasonable data rates, Wireless Local Area Network (WLAN) technologies harmonize fixed broadband connectivity with local area exposure for higher data rates. A mobile network operator could then attain a related increase in network capacity in dissimilar customs. They could prefer to advance the air interfaces in cellular systems, to arrange denser (heterogeneous) networks, to lease capacity from specialized (WLAN) network contributors and to split (radio access) transportation with additional operators.

To what extent these preferences are subjugated in practice will of course be crate explicit and eventually depend on a number of technical, financial, marketing and dictatorial factors. Hence, identifying universal supplies for future systems is a difficult work which is of great significance not only for the operators, but also for equipment retailer. In any case, as the production matures, it will become even more imperative for operators to minimize their cost of infrastructure for the targeted service contribution and this is the tip of departure for this paper.

For mobile telephony systems the dominating consumption strategy in this feature has been to minimize the number of base station sites and reclaim existing infrastructure as far as potential. This is quite reasonable since the cost of homogeneous wireless access networks is roughly proportional to the number of access points organized [3,4]. In a heterogeneous situation, however, that plan would not unavoidably minimize the total cost of a network since equipment, installation and operational costs all are less expensive for 'small' base stations [5, 6]. Moreover, the demand for area coverage, mobility and peak data rates may vary greatly between services [5].

II. ROBUST OPTIMIZATION METHOD

Unadventurously, problems have been explained pretentious the input data to be invariant. However, in practice, the comprehensions of the input data to the model are, more often than not, different from those unspecified in the mathematical model. This causes the solutions that are attained to be remote from optimal in real life, and in some cases, even infeasible. Models are naturally created by using `best-guess' values or mean-values of input data, or by resolving `worst-case' problems. Such `worst-case' or `best-

guess' formulations do not afford acceptable explanations. They are either too expensive (worst-case models) or have vast errors (mean-value models). We pass on to model inputs that are undetermined to be appreciated with certainty, as nominal values; the models devised using nominal inputs as nominal models, and the keys thus attained as nominal solutions. After accomplishing a case-study on the problems in the Net Lib library, Ben-Tal and Nemirovski [7] also fulfilled that in the real-world requests of linear programming, one cannot ignore the opportunity that a small uncertainty in the data can create the ordinary optimal solution entirely pointless from a realistic viewpoint"[8].

The widespread linear programming problem with robust optimization using MATLAB is the simulation in feasible solution for constraint problems. As a consequence, the simulation does not crutch up very well common linear programming features such as minimum cost network flow with uncertain demand. However, the widespread linear programming simulation will not be able to be handled by shifting the cost vector to gain vector. The relatively new robust optimization minimum channel gain flow problem is the best simulation which can switch minimum channel gain flow problem for maximizing the minimum throughput in heterogeneous wireless network. In the robust optimization minimum channel gain flow problem, the simulation is done on the equal power distribution and dynamic subcarrier project in OFDM.

III. IMPLEMENTATION

In this project, the minimum gain flow problem is used to simulate the uncertain network flow with robust optimization. The project consists of three main parts, minimum cost network flow simulation, minimum channel gain flow simulation (transform from cost vector to gain vector), and the signal to noise ratio for maximizing the minimum throughput simulation. The minimum channel gain flow simulation which is used to compute the minimum channel flow in heterogeneous wireless network. The signal to noise ratio for maximizing the minimum throughput simulation consists of signal to noise ratio and transmitted power. The user can cooperate both with the minimum channel gain flow simulation, and the signal to noise ratio for maximizing the minimum throughput simulation with MATLAB environments.

The overview of the program flow is shown on the Fig.1 on the same page. The simulation is realized in MATLAB language by using R2008b. In order to find minimum channel gain flow in uncertain network, simplex algorithm is premeditated in literature. Based on the research of robust optimization on network flow, robust optimization minimum channel gain flow method is specified and mathematical model are created with the wireless minimum channel gain network flow problem. The problem formulation is talented from the equal power distribution and dynamic subcarrier project with heterogeneous wireless network flow.
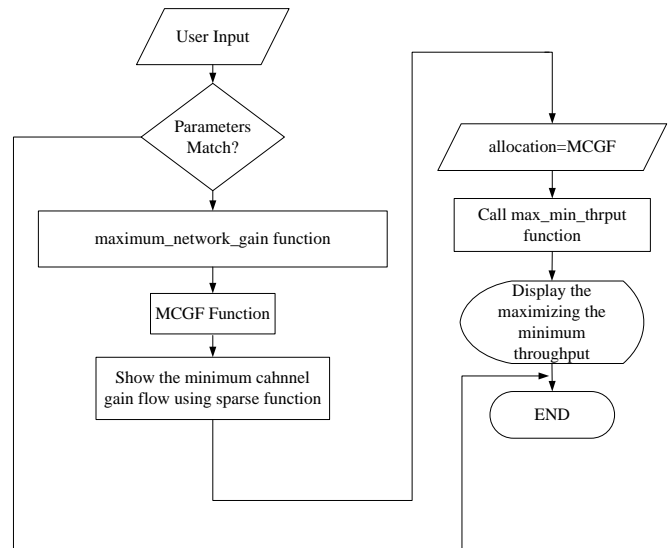

Fig.1. Program Flow

IV. EQUAL POWER DISTRIBUTION AND DYNAMIC SUBCARRIER PROJECT

In this advance, we contract with a system that skin dynamic sub-carrier project in combination with an equal power distribution per sub-carrier. Each sub-carrier n is allocated to at most one terminal j at time t, pointed out by a dual variable $a_{j,n}^{(t)}$ set to one ($a_{j,n}^{(t)}$ is set to zero if n is not allocated to j at t). Each sub-carrier is occupied with equal transmit power. The adaptive modulation system is practical on top of the dynamic sub-carrier project and eternal power distribution. For the selected goal, this results in an integer programming problem:

$$\max \epsilon$$

subject to $\sum_j a_{j,n}^{(t)} \leq 1$ for all n (ALLOC)

$$\sum_n I\left(\frac{s_n^{(t)} v_{j,n}^{(t)2}}{\sigma^2}\right) \cdot a_{j,n}^{(t)} \geq \epsilon \quad \text{for all j(FAIR)}$$

where $\sum_n I\left(\frac{s_n^{(t)} v_{j,n}^{(t)2}}{n^2}\right)$ illustrates the number of bits per downlink phase that can be broadcasted on sub-carrier n for terminal j at time t with a send out power of $s_n^{(t)}$ (thus, this function molds the adaptive modulation structure, depending also on the target SEP). The first constraint (ALLOC) guarantees the project of at the majority one terminal to one sub-carrier at a time. The second constraint (FAIR) apparatus the argued objective: Maximizing the bare minimum throughput per terminal per down-link phase. Note that no extra constraint for the transmit power is necessary as the power is statically dispersed. In addition, notice the number of feasible solutions for this integer programming dilemma. Each sub-carrier can be allocated to one out of J terminals, thus a total of J^N potential solutions survive.
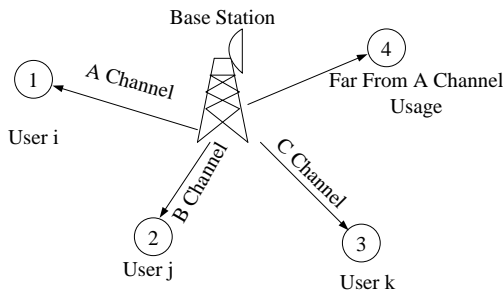
Fig.2. Equal Power Distributions for Heterogeneous Wireless Network

A. Creation of Maximizing the Minimum Throughput

This Algorithm.1 is to find the maximizing the minimum throughput. To find the maximizing the minimum throughput in network flow problem, we have to assign the following parameters into the MATLAB function. They are SNR is defined as the instant SNR of subcarrier n for terminal j at time t, Power is also cleared the transmission power, Channel is separated the attenuation of subcarrier, and noise_power is assigned the noise power.

After conveying these variables, the maximizing the minimum throughput function can be written by the following instructions.

```
Algorithm.1. Finding the maximizing the minimum throughput
begin
    Declare appropriate parameters for signal to noise ratio as
    snr_{j,n}^{(t)} = ( a_n^{(t)} Y_{j,n}^{(t) 2} / n^2 );
    Determine SNR with power flow, channel and noise power
        SNR=power*channel.^2/noise_power;
    Determine minimum throughput with allocation from mcnf and
dB of SNR
        minimum_throughput=log10(1+SNR)*allocation;
    Select the maximum value of minimum throughput
    maximizing_the_SNR=max(minimum_throughput);
    maximizing_the_minimum_throughput=max(maximizing_the_SNR));
    Plot the SNR with respect to transmitted power
end
```

B. Creation of Maximum_Network_Gain

This function is to calculate the best case gain for uncertain demand network flow. For each arc, we have calculated the current flow value. Furthermore, we have to know the minimum and the maximum gain value on this arc. Then the best case gain is the sum over all arcs of (flow on arc)*(minimum gain on this arc).

```
Algorithm.2. Creation of maximum_network_gain
begin
    Inilize Gchmax=0;
    To find maximum channel gain along that network flow
        for i=1 to n
        Calculate the maximum channel gain with channel and
maximum gain
            Gmax = channel*Gmax;
            Gchmax=Gmax+Gchmax;
        end
        Select the minimum or maximum values of Gchmax
        min-Gchmax= min(Gchmax)
        max-Gchmax= max(Gchmax)
end
```

The detailed instruction is given in Algorithm.2. In this Algorithm, the Channel_ Pair_Node_Incidence_Matrix is got from the reference network model in robust optimization.

C. Creation of Minimum_Network_Gain

This function is to calculate the worst case gain for uncertain demand network flow. For each arc, we have calculated the current flow value. Furthermore, we have to know the minimum and the maximum gain value on this arc. Then the worst case gain is the sum over all arcs of (flow on arc)*(maximum gain on this arc). The detailed instruction is given in Algorithm.3.

```
Algorithm.3. Creation of minimum_network_gain
begin
    Inilize Gchmin=0;
    To find minimum channel gain along that network flow
        for i=1 to n
        Calculate the minimum channel gain with channel and
maximum gain
            Gmin = channel*Gmin;
            Gchmin=Gmin+Gchmin;
        end
        Select the minimum or maximum values of Gchmax
        min-Gchmin= min(Gchmin)
        max-Gchmin= max(Gchmin)
end
```

D. Creation of MCGF

The detailed instruction is given in Algorithm.4. After declaration the above input variables for creation of mcgf function, we have to call linprog.m from the MATLAB library to execute the mcgf for twenty allocations for the uncertain network flow. If the parameters from mcgf function change by the necessary allocation condition, the user can easily be changed by sufficient parameters with linprog function.

```
Algorithm.4. Creation of mcgf
begin
    N=(K,A,u,S);
    i(f)=0; stop:=false; N(f)=N;
    while(i(f)≠i0 and stop=false) do
    begin
    determine a robust minimum augmented chain with respect to 1
from node i1 to in in N(f);
    let R denote the robust minimum augmented chain;
    if A(R)≠Φ then
        augment unite of flow along R;
        i(f)=i(f)+1;
        update the reduced network N(f);
    else
    stop:=true;
        end
        if i(f)≠i0 then
        Print (The problem is infeasible);
        else
        return f;
end
```

E. Creation of Robust Optimization Max- Channel Gain

There are two main parts in this robust optimization channel gain main function. The first one is to call the maximum_network_gain function to calculate the gain in dB and the second one is to display the network flow with graph function. For the display section, we have to assign the number of rows "m", number of sinks, number of sources, and number of arcs that the problem generates to each node. If we want to delete some of the arcs to get a more difficult (but smaller) problem, we have declared the value of del as1.

The number of deleting iterations is assigned to kmax =3.

The minnod=4 is the minimal number of arcs at each node. The nodes that have smaller number of arcs then minnod in the beginning will not be changed. The maximal number of arcs that can be taken away as away=4. If the solution will be limited by ub, we have to declare as lim=0. If we want to see the graph of the problem, we have to declare as graph=1. If we want to see which nodes that are sinks or sources, we have to declare as dispnode=1. If we want to change the problem after we have seen the graph then switching revise to 1, we have to declare as revise=0.

If the result from summation of source and sink is greater than the number of row "m", we have to inform the warning message for the user. After accomplishing the above declaration for user, the location of source node and sink nodes have to be placed on the limited boundary on the graphic window of the MATLAB. So the location of source and sink nodes can be expressed as real and imaginary portion of the graph. According to the graph function or sparse function, the location of each node will be displayed on the monitor. And then the flow of source node to sink node can be placed by row and column matrices with find function.

The initial location of source node will be transformed by replacing with the sink node. And the above rules are appropriate algorithm for final destination node for uncertain demand. Due to the solution of upper bound ub is limited by lim=0, the final sink node will be found by certain interval or period. The graph function will be activated according to the matching state of the above parameters. The linprog.m function is also called from the matrix of inequality constraints "A". If the display function is also activated with the graph results of minimum cost network flow solution, it can be transformed to minimum gain flow solution by changing the cost vector to gain vector of optimization network flow.

F. Linking for Network Flow Optimization and Power Flow

The above expression of minimum channel gain flow function produces the channel allocation for maximizing the minimum throughput function. Based on the result from the mcgf.m function, the value of maximizing the minimum throughput is generated by applying the maximum and minimum network gain functions. The mcgf.m function is only applied to generate the allocation and optimal solution or maximum or minimum power flow of the robust optimization network flow. The above mention is got from the ideas of gain vector with cost vector of minimum cost flow problem. If the user is applied to find the minimum gain flow for heterogeneous wireless network, the channel allocation will be got from the result values of mcgf.m function.

V. RESULTS

We performed three simulations with different settings to in order test certain features of the simulation. The first simulation was the maximizing the minimum throughput and signal to noise ratio with transmitter imitation. The minimum throughput essentially depends on the channel and allocation. However, if the number of channel is three, the proposed network flow will be displayed. On the second simulation, we

focused on the decreasement of allocation for the mgnf.m function. Finally, in the third simulation, we wished to check how the incensement of the allocation could affect the maximizing the minimum throughput and signal to noise ratio with transmitter simulation, thus we used an object in this simulation but we increased the allocation.

A. First Simulation

The Channel_Pair_Node_Incidence matrix results are illustrated as the minimum channel gain flow graph of Fig .3. According to the following figure, the minimum channel gain flow solutions are found easily by colour lines.
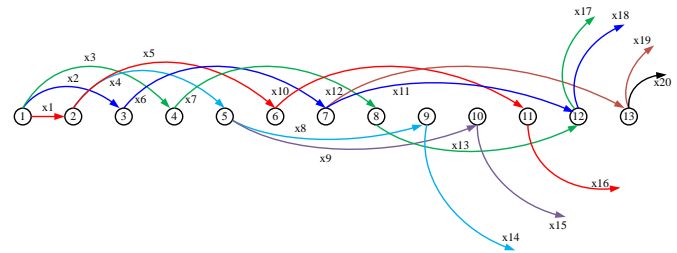

Fig.3. Minimum Channel Gain Flow Graph

According to the simulation results the minimum value of maximum channel gain is 444 and maximum value of maximum channel gain is 469. The conversion of power flow with respect to the respective arc of the minimum channel gain flow problem of robust optimization basic demand curve is illustrated in Fig.4. The red colour line is represented as the power flow for the reference model of the minimum channel gain flow problem.
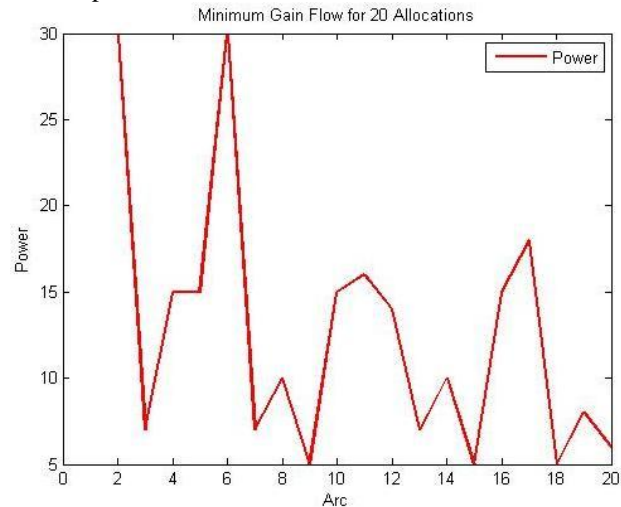

Fig.4. Conversion of Power Flow with respect to the Respective Arcs

The optimal solution from the mcgf.m function is 1.3837e+003 and the signal to noise ratios for the twenty channel network model are calculated from the max_min_thrput.m function with respect to the channel allocations and power control flow of the network model. According to the simulation results, the value of maximizing the minimum throughput for 20 Allocations is 30.45 dB. The SNR values curve is shown in Fig.5. From Fig.5, the signal to noise ratio is depends only on the transmitted power. If the transmitted power is increased to a certain level of power, the

signal to noise ratio will be increased with the appropriated function. According to the results for the 22 allocations and 3 channels for reference model of network flow, the value of maximizing_the_minimum_ throughput is matched with the wireless heterogeneous model in OFDM.
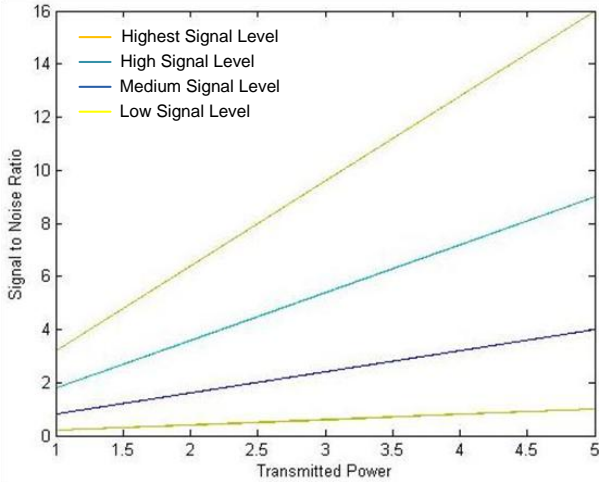

Fig.5. Result of SNR with respect to Transmitted Power for 20 Allocations

The following Fig.6 shows the screenshot of the simulation with the first simulation for basic demand. The screenshots were taken in final results of execution. We can see from the images that the first simulation correctly interacts with the minimum throughput in which the certain network flow. According to the Fig.6, the red color spot is represented by source node and the five blue colors spot is also represented by the destination or sink node.
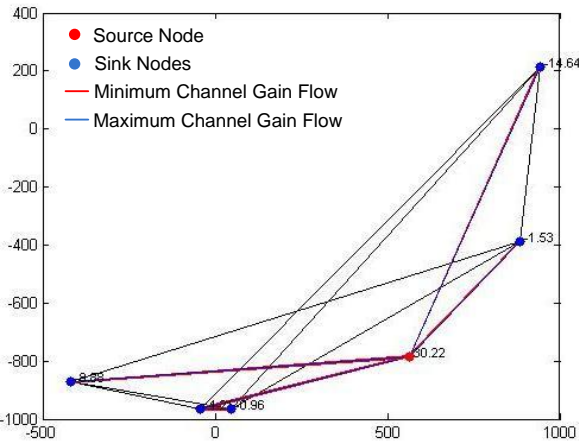

Fig.6. First Simulation Result for Basic Demand

B. Second Simulation
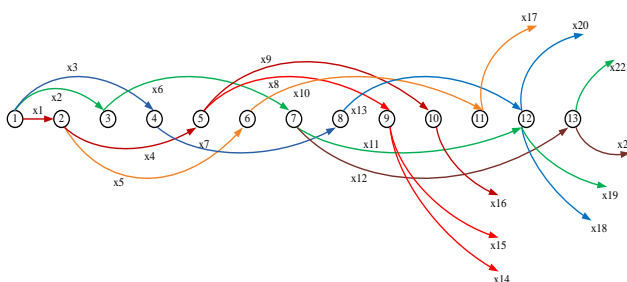

Fig.7. Maximum Channel Gain Flow Graph

The Channel_Pair_Node_Incidence matrix results are illustrated as the minimum channel gain flow graph of Fig.7. The conversion of power flow with respect to the respective arc of the minimum channel gain flow problem of robust optimization full demand curve is illustrated as Fig.8. The blue colour line is represented as the power flow for the reference model of the minimum channel gain flow problem.
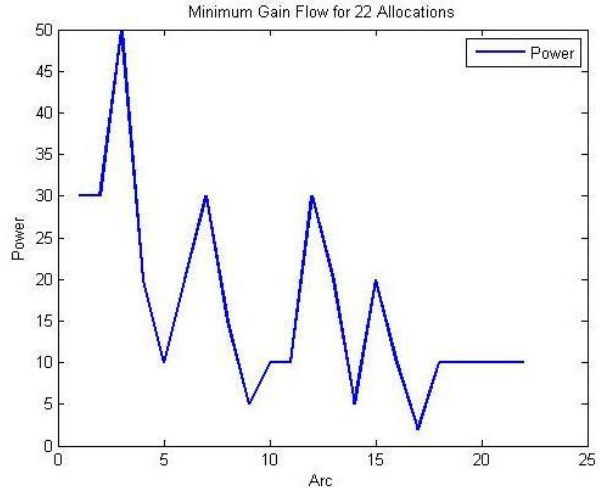

Fig.8.Conversion of Power Flow with respect to the Respective Arcs

According to the simulation results the minimum value of maximum channel gain is 1130 and maximum value of maximum channel gain is 1170. The optimal solution from the mcgf.m function is 811.6097and the signal to noise ratio for the twenty channel network model is the same as Fig.5. It consists of twenty two rows and twenty two columns. These values are proposed from the max_min_thrput.m function with respect to the channel allocations and power control flow of the network model. According to the simulation results, the maximizing_the_minimum_throughput is 25.10 dB.

If we change the 22 allocations and 3 channels in that network flow, the following simulation results for full demand will be viewed. Fig.9 shows the screenshot of the second simulation result for full demand. The screenshots were taken in final results of implementation. We can see from the images that the first simulation correctly interacts with the minimum throughput in which the certain network flow.
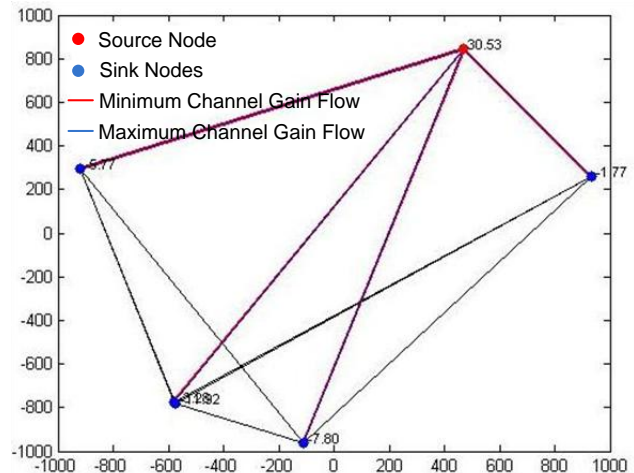

Fig.9.Second Simulation Result for Full Demand

C. *Performance Evaluation of Basic and Full Demand*

The performance evaluation of basic demand and full demand is illustrated in Fig.10. In this figure, the red color line represents the performance of basic demand and the blue color line represents the performance of full demand condition. These curves fluctuate by depending on the running time. But this fluctuation is caused by flow or allocations and power control of the network model for robust optimization uncertain network flow.
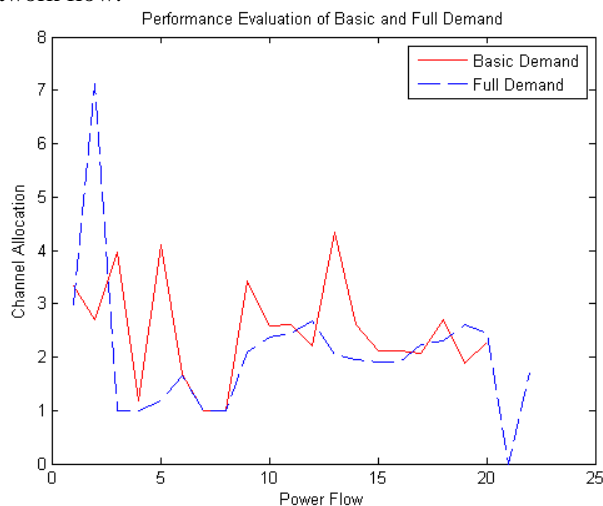

Fig.10. Comparison Curves of Basic and Full Demand

VI. CONCLUSION

The shortcoming of the minimum cost network flow with robust optimization simulation is that if the number of allocations is more than 20, the maximizing_the_ minimum_throughput will be low. In spite of the simplicity of minimum cost network flow with robust optimization simulation and the aforementioned disadvantages, our implementation of minimum cost network flow with robust optimization can be used to simulate network flow in uncertain demand realistically as we presented in section V. For example, in the first experiment the maximizing_the_minimum_throughput is 30.45 dB. For the second experiment, we could examine that the maximizing_the_minimum_throughput is 25.10 dB. Moreover, the signal to noise ratio with respect to transmitted power from the two experiments are roughly the same. We also successfully realized the network flow so that the heterogeneous wireless network could interrelate in the mobile communication correctly, such as the source easily connect to the sink of the network flow. Finally, we successfully executed the user interaction feature such that the user can insert external parameters and others to the simulation as well as flowing through the network in heterogeneous wireless communication.

ACKNOWLEDGMENT

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