Study and Implementation of Power Control in Ad hoc Networks

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Computer Science and Engineering

By

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Department of Computer Science and Engineering
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CERTIFICATE

This is to certify that the thesis entitled “Study and Implementation of Power Control in Ad-Hoc Networks” submitted by Ankit Saha and Chirag Hota in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Computer Science and Engineering at National Institute of Technology, Rourkela (Deemed University) is the simulation of two existing protocols carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date:

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Abstract

An ad hoc network facilitates communication between nodes without the existence of an established infrastructure. Random nodes are connected to one another using Ad hoc networking and routing among the nodes is done by forwarding packets from one to another which is decided dynamically. The transmission of packets among the nodes is done on a specified power level. Power control is the method used for transmission of the packets at an optimized power level so as to increase the traffic carrying capacity, reduce the usage of battery power and minimize the interference to improve the overall performance of the system with regards to the usage of power. This thesis tells us regarding COMPOW (Common Power) and CLUSTERPOW (Cluster Power) protocols, which are two existing protocols for power control in homogeneous and non-homogeneous networks respectively. We have implemented these two protocols in Java Platform and run it for different number of nodes. From the implementation we have come up with the power optimal route among the nodes and the routing table for each node for both homogeneous and non-homogeneous networks.

COMPOW (Common Power) protocol is an asynchronous, distributed and adaptive algorithm for calculating the common optimized power for communication among different nodes.

CLUSTERPOW (Cluster Power) protocol is a protocol designed for optimizing the transmit power and establish efficient clustering and routing in non-homogeneous networks.

CHAPTER 1

INTRODUCTION

1.1 WIRELESS NETWORKS

Any type of computer network which is wireless is known as a wireless network. It is commonly used in telecommunication network where wire is not the mode of connectivity among the nodes[5]. The various types of wireless networks are:

1. Wireless LAN (Local Area Network)

2. Wireless PAN (Personal Area Network)

3. Wireless MAN (Metropolitan Area Network)

4. Wireless WAN (Wide Area Network)

5. Mobile Devices Network

Wireless networks are basically used for sending information quickly with greater reliability and efficiency. The usage of wireless networks range from overseas communication to daily communication among people through cellular phones .One of the most extensive use of wireless network is Internet connectivity among the countries. However, wireless networks are more prone to outside threat from malicious hackers and are hence vulnerable.

1.2 WIRELESS AD HOC NETWORK

Ad hoc networks are a new paradigm of wireless communication for mobile hosts (which we call nodes). In an ad hoc network, there is no fixed infrastructure such as base stations or mobile switching centers. Mobile nodes that are within each other's radio range communicate directly via wireless links, while those that are far apart rely on other nodes to relay messages as routers. Node mobility in an ad hoc network causes frequent changes of the network topology [1].
In a wireless Ad hoc Network, routing is done at each node by forwarding the data to other nodes and the forwarding by nodes is decided dynamically based on the connectivity among the nodes.
Being a decentralized network and easy to set up, wireless ad hoc network find their usage in a variety of applications where the central node is not reliable. However in most ad-hoc networks the competition among the nodes results in interference which can be reduced using various cooperative wireless communications.

1.3 POWER CONTROL IN AD HOC NETWORKS

Power control basically deals with the performance within the system. The intelligent selection of the transmit power level in a network is very important for good performance. Power control aims at minimizing the traffic carrying capacity, reducing the interference and latency, and increasing the battery life.

Power control helps combat long term fading effects and interference. When power control is administered, a transmitter will use the minimum transmit power level that is required to communicate with the desired receiver. This ensures that the necessary and sufficient transmit power is used to establish link closure. This minimizes interference caused by this transmission to others in the vicinity. This improves both bandwidth and energy consumption. However, unlike in cellular networks where base stations make centralized decisions about power control settings, in ad-hoc networks power control needs to be managed in a distributed fashion [2].

Power control is a cross-layer design problem .In the physical layer it can enhance the quality of transmission. In the network layer it can increase the range of transmission and the number of simultaneous transmissions. In the transport layer it can reduce the magnitude of interference.

1.4 PROJECT DESCRIPTION

The aim of the thesis is to find the lowest common power level for an ad hoc network in which the network is connected for both homogeneous and non-homogeneous networks. For this there are two existing protocols [3][4] COMPOW protocol and CLUSTERPOW protocol. These power control protocols find the lowest common power levels for homogeneous and non homogeneous networks respectively. We found the routing table for each node in the network and then found the optimized route using Bellman Ford Algorithm that considers power as metric. From the optimized route we show the connectivity among the nodes at different power levels and compare the connectivity and efficiency of transmission among the nodes at different power levels.

1.5 THESIS ORGANIZATION

The thesis is organized into chapters where we start with the literature review of the existing algorithms. We started with studying the existing protocols COMPOW and CLUSTERPOW for power control in ad hoc networks. For the Implementation of these protocols we use Bellman Ford algorithm which uses power aware routing taking power as a metric[7].

We have done the simulation of the protocols in JAVA to get the results.

In the first chapter we give a brief overview about wireless networks, wireless ad hoc networks and Power Control in ad hoc networks. In the second chapter we describe power control in ad hoc networks in detail .We describe the importance of power control , how power control affects various layer and regarding transmit power. In the third and fourth chapter we describe the two existing protocols COMPOW and CLUSTERPOW in detail. We describe their connectivity, algorithm, advantages and limitations. We also provide information regarding the enhancements that can be or has been done for filling the loopholes of these protocols. In the fifth chapter we show the results of the simulation in the form of snapshot. Finally we conclude the thesis in the sixth chapter.

CHAPTER 2.

POWER CONTROL

2.1 INTRODUCTION

Power control is the intelligent selection of lowest common power level in an ad hoc network in which the network remains connected. The power optimal route for a sender receiver pair is calculated and the power level used for this transmission is set as the lowest power level for that particular transmission. In case of multiple nodes, power optimal route for each transmission is calculated. The importance of power control arises from the fact that it has a major impact on the battery life and the traffic carrying capacity of the network. In the subsequent topics we discuss how power control affects various layers.

2.2 IMPORTANCE OF POWER CONTROL

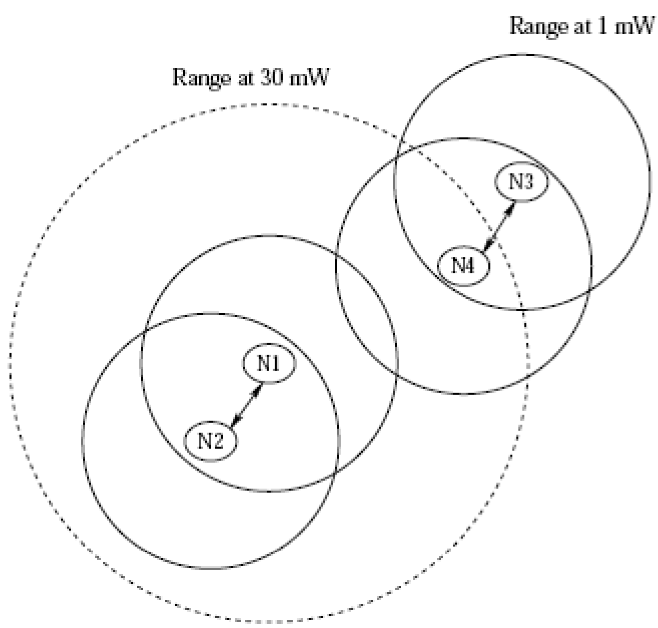

Figure 2.1-The need for power Control [3]

In the figure 2.1 we can see that there are two transmissions occurring simultaneously between nodes N2 and N1 and nodes N4 and N3. From the figure we can see that node N2 can transmit data to node N1 at both 30mW and 1mW. However, if it transmits at 30mW then there will be interference between the two transmissions N1-N2 and N3-N4. So the power control scheme helps us to select a common power level at which both the transmissions can occur concurrently without any interference among one another .This helps in increasing the traffic carrying capacity of the network [3].

2.3 POWER CONTROL IN THE LAYERED HIERARCHY

Power control is not subjective to a single layer. It affects multiple layers of the layered hierarchy.

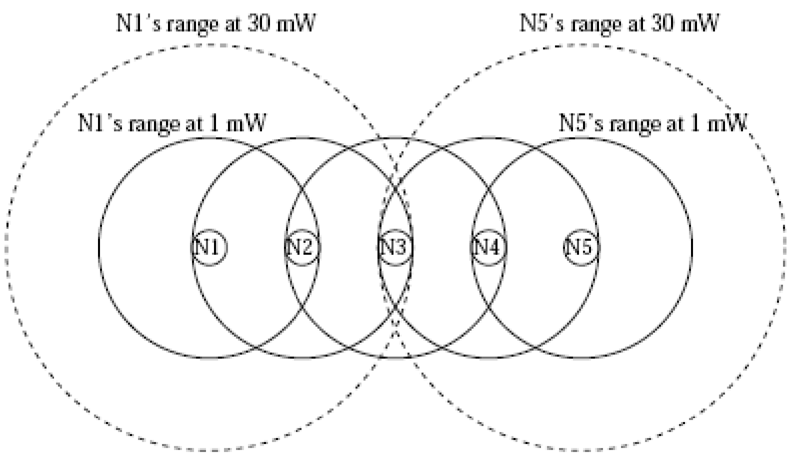

Figure 2.2-Power Control in Network Layer [3]

In the figure 2.2 there will be different routes between the two nodes for different power level selections .Suppose all nodes transmit at 1mW then the route from node N1 to N3 will be N1-N2-N3. However when the nodes transmit at 30mW, then there will be direct transmission between N1 and N3 since both of them come under that particular power level. So we can clearly see that the selection of a common power level affects the route and hence the network layer [3].

In the figure 2.3, we can see that if node N1 transmits at a higher power level to node N2 then it will cause interference in the transmission between node N3 and N4. This will result in the loss of a large number of packets sent from N3 to N4. Also it will affect the flow of data packets from N4 to N5 that uses the congestion control algorithm to relay the packets via the node N3. Hence power control also affects the transport layer [3].

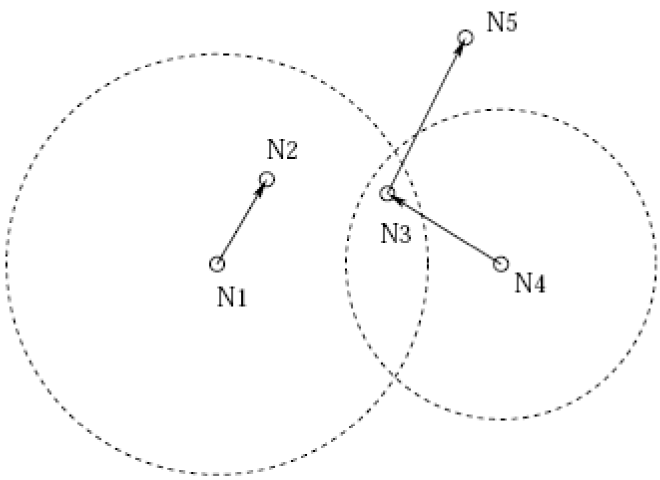

Figure 2.3-Power Control in transport layer [3]

2.4 TRANSMIT POWER

Transmit power level is the power level at which the transmission among the nodes take place. Increasing the transmit power level has it's own advantages. A higher transmit power level means a higher signal power at the receiver end .So the signal to noise ratio is significantly increased and the error in the link is thus reduced. When the signals in a network keep on fading, it is advantageous to use a high transmit power so that the signals received at the receiver's end is not that weak. However high transmit power has quite a few disadvantages. The overall consumption of battery by the transmitting device will be high. Interference in the same frequency band increases drastically. Hence the need for an algorithm arises that can select an optimum transmit power level in a network.

CHAPTER 3.

COMPOW PROTOCOL

3.1 INTRODUCTION

COMPOW (Common Power) protocol provides an asynchronous, distributive and adaptive algorithm which finds the smallest power level at which at which the network remains connected. The protocol provides bidirectionality of links and connectivity of the network, asymptotically maximizes the traffic carrying capacity, provides power aware routes and reduces MAC layer contention.[3]

3.2 CONNECTIVITY

We generate nodes randomly on a surface area 'S' square meters and assign them with specific x and y coordinates for each node generated randomly. For each source destination pair we check that whether the distance between them is less then 'm' (the range in meters of each node). Then we check for the interference in transmission among the nodes .We take up an interference parameter n (assumed to be much less than the range m). We check that the distance between the nodes of two simultaneous transmission is less than (1+n)*m.

Suppose the rate at which the sender wants to send a data packet to receiver is 'a' bits per second. There is a reciprocal dependency between the rate a and the range m.[3] Hence we need to decrease the m value .However very low values of m may result in a disconnected network. So we need to choose a r value at which the network remains connected and this suffices our aim of finding lowest common power level at which the network remains connected.

3.3 COMMON POWER LEVEL

In power aware routing preference is given to a large number of smaller hops rather than few long hops. So in order to find the lowest common power level one of the prime criterion is to find the most optimized route between the sender and the receiver.

Suppose there is a transmission between two nodes A and B. Let the minimum power level required for the transmission be 'w' mill watts. Let the power loss in a particular path follow the inverse p^{th} law. So for a distance 'a' (distance between sender and receiver) the received power level using a transmission power level P is equal to $(k*P)/(a^p)$.For a successful transmission the received power must be greater than the power required for transmission, i.e

$$(k*P)/(a^p) \geq w$$

So the transmission power level, P has a minimum value of $(w/k)* a^p$.

Now for ‘n’ number of hops, the transmission power level $P = (w/k)[a_1^p + a_2^p + \dots \dots \dots a_n^p]$

i.e. $P = \sum (w/k)[a_i^p]$

Ignoring the scaling factor (w/k), P is directly proportional to a_i^p .

Hence an optimal route will give the lowest common power level in a connected network.

So we find the optimal route using the Bellman-Ford algorithm and find the power associated with the optimal route and choose it as the common power level [3].

3.4 ADVANTAGES

The COMPOW protocol increases the traffic carrying capacity, reduces the battery consumption i.e. increases the battery life, reduces the latency, reduces interference, guarantees bidirectional links ,provides power aware routes and can be used with any proactive routing protocol.[3]

Another feature of the COMPOW protocol is the plug and play capability. It is among the very few protocols that has been implemented and tested in a real wireless test bed. [3]

3.5 LIMITATIONS

When the nodes in a network are clustered the COMPOW protocol may settle for an unnecessarily high power level [3] .Even a single node outside the cluster may result in a high power level selection for the whole network. COMPOW protocol works only for homogeneous networks.

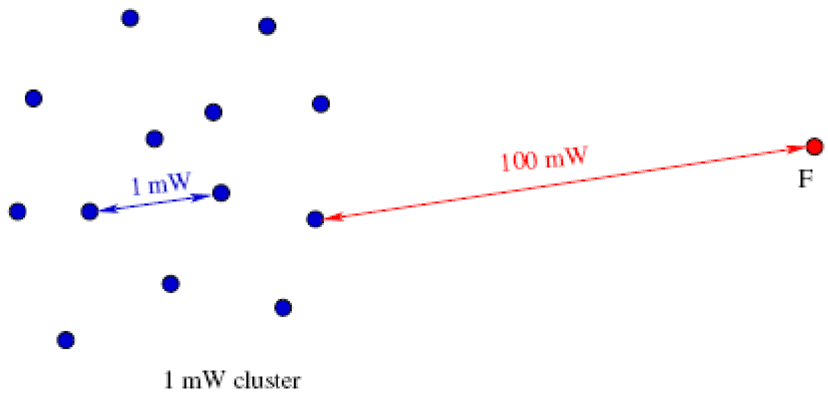

Figure 3.1-A common power level is not appropriate for non-homogenous networks [4]

In the figure 3.1, there is a cluster in which the nodes transmit at 1 mW power level. The node F outside the cluster needs a power level of 100 mW for transmission. So the single node F outside the cluster can force the common power level for the network to a high value. Hence COMPOW is not suitable for clusters.

3.5 ENHANCEMENT

In the next chapter we describe how to find the lowest common power level in a cluster using an existing protocol CLUSTERPOW that fills the loopholes of the COMPOW protocol.

CHAPTER 4.

CLUSTERPOW

4.1 INTRODUCTION

CLUSTERPOW protocol provides us with implicit, adaptive, loop free and distributed clustering based on transmit power level. The routes discovered in this protocol consist of a non-increasing sequence of transmit power levels. CLUSTERPOW is an enhanced version of COMPOW as CLUSTERPOW is used in non-homogenous network whereas COMPOW is used where the network is homogenous. We can use CLUSTERPOW with both reactive and proactive routing protocol. It finds the lowest transmit power at which the network is connected.[4]

4.2 CONNECTIVITY

We generate nodes randomly on a surface area ‘S’ square meters and assign them with specific x and y coordinates for each node generated randomly. In CLUSTERPOW multiple routing daemons are running, each one corresponding to each power level pl_j in a finite and discrete set of feasible power levels. All these routing daemons build their own separate routing tables $RTpl_j$ by communicating with their peer routing daemons of the same power level at other nodes, using hello packets transmitted at power level pl_j. The next hop in CLUSTERPOW is found by consulting the lowest power routing table where the destination is reachable. As we go from the source toward the destination the power level at every intermediate node is non-increasing. That is, for every destination D, the entry (row) in the kernel routing table is copied from the lowest power routing table where D is reachable, i.e., has a finite metric. The kernel routing table has an additional field called the transmit power (txpower) for every entry, which indicates the power level to be used when routing packets to the next hop for that destination. [4]

4.3 ADVANTAGES

The CLUSTERPOW protocol increases the network capacity, reduces the battery consumption i.e. increases the battery life, reduces interference and it is loop free. It takes care of non-homogenous networks. The traffic-carrying capacity of the network can be shown by taking into consideration the additional relaying burden of using small hops versus the interference caused by long hops, it is optimal to reduce the transmit power level [4].

4.4 LIMITATIONS

CLUSTERPOW does not take care of consumption of energy in transmitting the packets in the network. While CLUSTERPOW takes care of the network capacity, the power consumption in processing while transmitting and receiving is typically higher than the radiative power required to actually transmit the packet [4].

4.5 ENHANCEMENTS

The limitations of CLUSTERPOW protocol can be overcome using two existing protocols: Tunneled CLUSTERPOW and MINPOW protocol.

The MINPOW protocol reduces the energy consumption in sending packets over the network.

In Tunneled CLUSTERPOW recursive lookup scheme can be modified so that it is indeed free of infinite loops. This is done by tunneling the packet to its next hop using lower power levels, instead of sending the packet directly. One mechanism to achieve this is by using IP in IP encapsulation. Thus, while doing a recursive lookup for the next hop, we also recursively encapsulate the packet with the address of the node for which the recursive lookup is being done. The decapsulation is also done recursively when the packet reaches the corresponding destination [4].

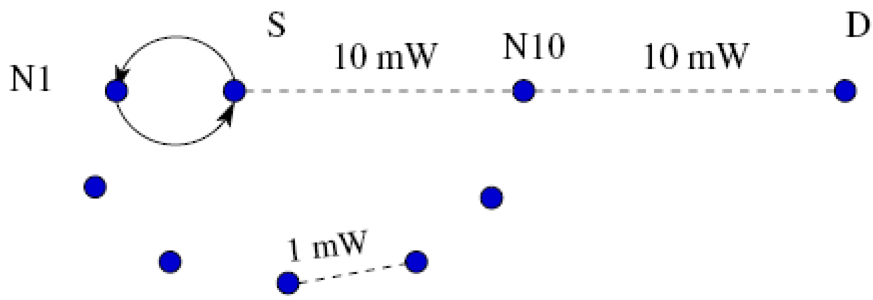

Figure 4.1-The recursive lookup scheme is not free of infinite loops [4]

In the figure 4.1 we can see that N1-S transmission requires a power level less than that of transmission from S to any other node (i.e. the next hop). So since the algorithm finds for a hop of non increasing power level, the next hope is traced back to N1. This results in an infinite loop.

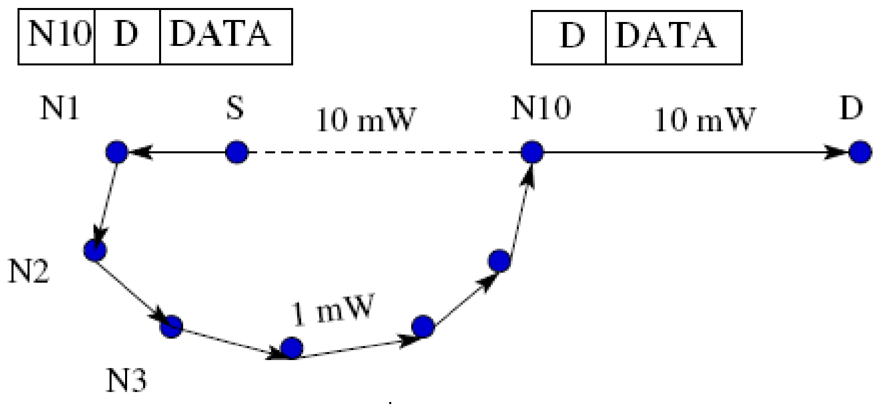

Figure 4.2-Tunnelled CLUSTERPOW protocol resolves infinite routing loop of the network [4]

In figure 4.2, instead of sending the packet directly we send it through hops of lower power level. At the source encapsulation of packet is done with the destination address being N10 and not D. The packet is sent to N1 first which transmits the packet through hops of lower power levels to reach N10. At N10 decapsulation of the packet is done and the data is sent to D at 10 mW power level.

CHAPTER 5.

RESULTS

5.1 GENERATION AND CONNECTIVITY OF NODES

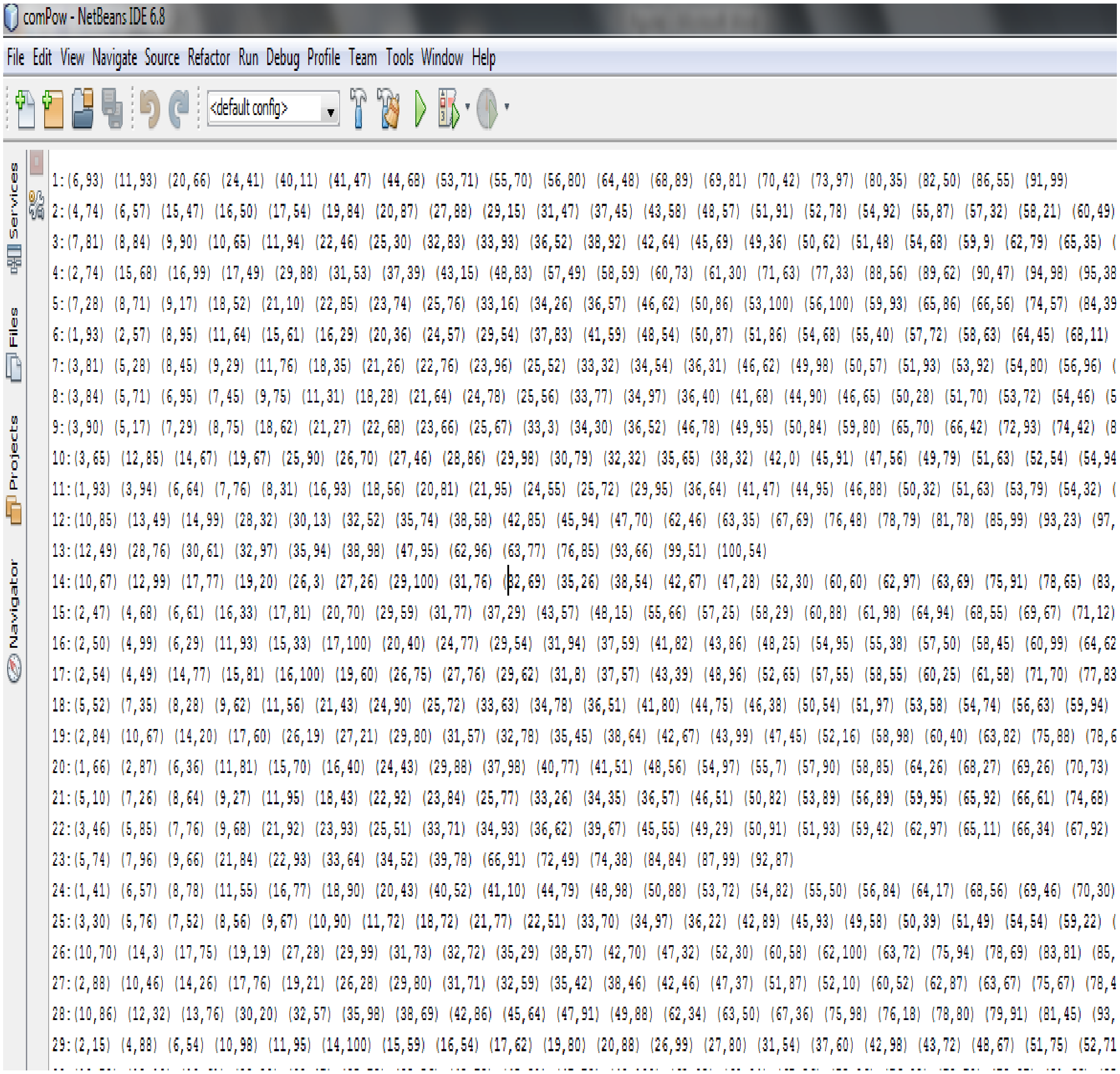

Figure 5.1-Random nodes generation and transmit power required

A: (D,P) implies for node A to transmit data to node D the amount of transmit power required is P mW.

P has a range of 10 mW to 100 mW.

5.2 OUTPUT FOR COMPOW

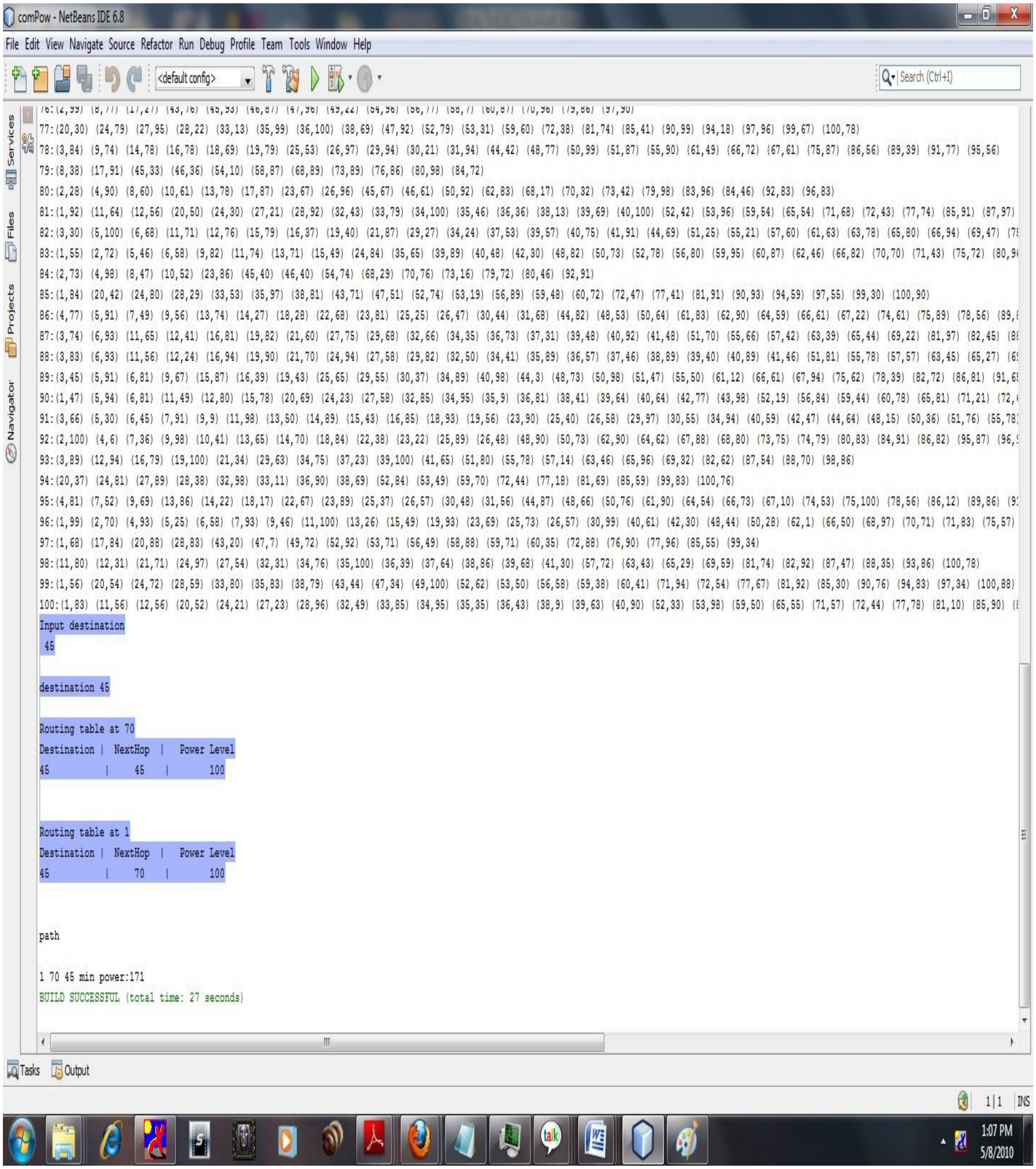

Figure 5.2–Routing Table Generation for COMPOW

The routing table provides information regarding the destination, next hop and the power level at which the transmission is taking place.

5.3 OUTPUT FOR CLUSTERPOW

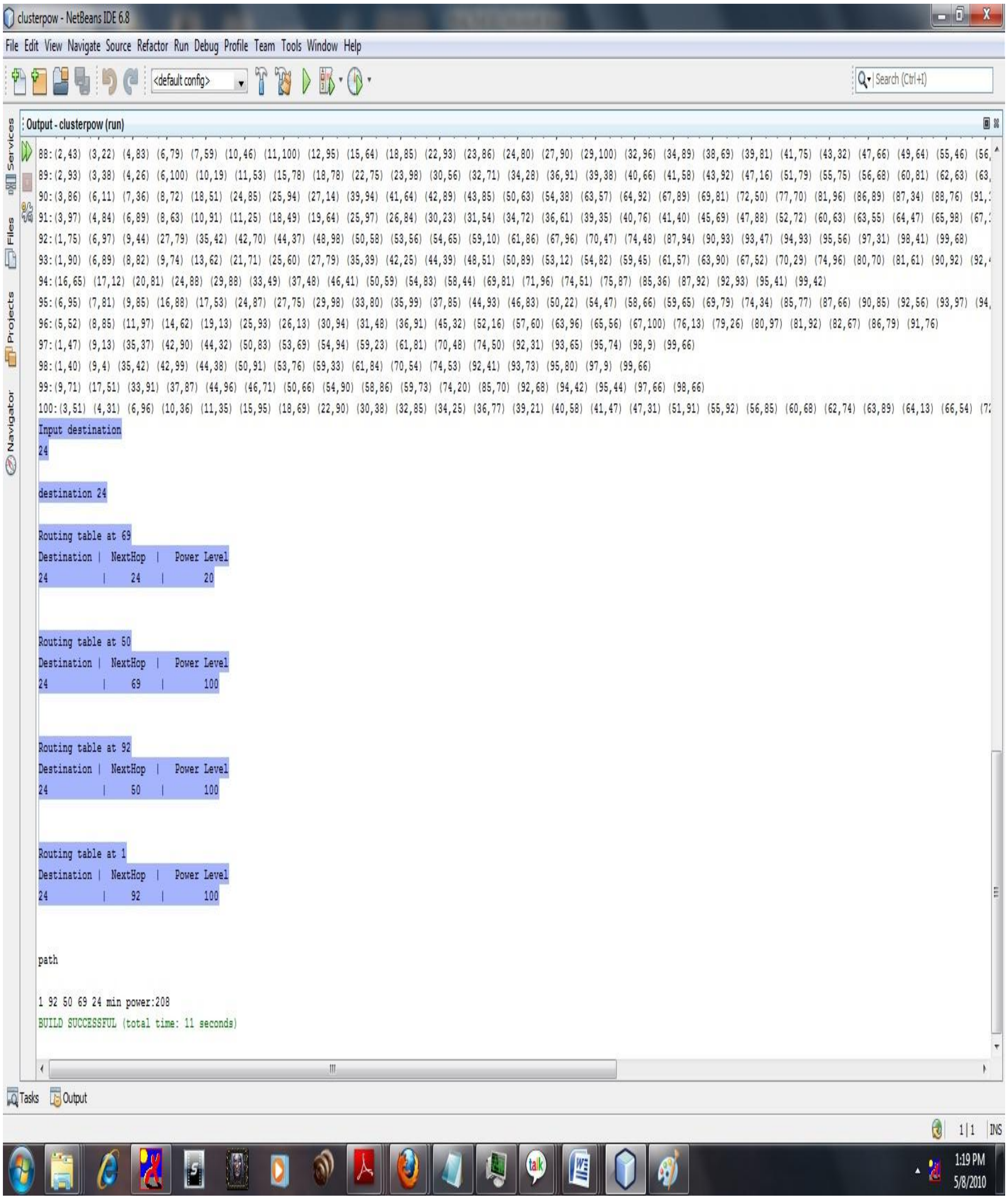

Figure 5.3-Routing Table Generation for CLUSTERPOW

The routing table provides information regarding the destination, next hop and the power level at which the transmission is taking place.

CHAPTER 6.

CONCLUSION

CONCLUSION

In this paper we have implemented two existing protocols for Power Control in ad hoc networks: COMPOW and CLUSTERPOW. We have done the simulation in JAVA. Simulation of the protocols was done in constant nodes and power level was taken as the metric to compare the performance. We have constructed the routing tables for the transmission of data among the nodes and calculated the minimum transmit power required for the transmission.

The results of simulation confirm that COMPOW protocol is better for homogeneous networks and it is not suitable for clusters whereas the CLUSTERPOW is better for non-homogeneous networks.

So we can conclude that no single protocol supersede any other protocol. The performance of the protocols depends upon the different scenarios it is subjected to.

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