Background

Nowadays, Wireless Sensor Network system has the main role in our daily life. It's has been integrated to many things. For example automation system, monitoring system, alarm system and etc. We are interesting in WSN on agricultural field.

Normally, WSN in agriculture is used as environment monitoring node with alert. Research from gathered data not only improve the technique to plant but also increase the efficient benefit to farmer. The general agricultural application can be employed for forest/vegetation monitoring, animal tracking, fire prevention and etc. Most of the sensor nodes will use for detect many parameters such as Temperature, Humanity, Pressure, Soil moisture or even soil acidity. These data will keep into log file and send to each other until the data reach to server node and then process data and display the result.

Although nowadays many WSN are expanded, not all devices or nodes can work as it works in experimental room as researcher thinks. As a result, to prevent this issue, experiments in different factors with appropriate recommendations are required.

There are some questions with the success/totalsend packet transmit rate. How many packets will loss during the transmission? How many packets will successfully reach to the base node? What factors have affected to these node? These questions become to be the design of experiment to figure out what factor has significant effect to the success rate ratio and what factor is not.

Objective

1. To figure out which factors have the most significant effect to the response.
2. To figure out the best factor value to find the best response for WSN performance.

Response Variable

Response	Unit	Relationship to objective
success/totalsend	%	100 % means can send all packets to base node. 0 % means all packets have loss in transmission.

Factor

Design Factor	Held-constant factors	Allowed to vary factors	Uncontrollable factors
Number of Nodes	Place	Wind	Wind
Distance between node	Person in experiment	Light	Electric noise interfere
Data size			

Factor Detail

Factor	Description	Predict
Distance between node	We set up the range between node in 20m, 40m and 80m and place in same experiment room.	Low distance between node will have more success rate than the longer one.
Data size	The data size in random text file will have size 5 byte, 10 byte and 15 byte.	The data size should not significant affected to success/totalsend rate.
Number of nodes	We create nodes and place in experiment room for 2 and 3 nodes	Less nodes will have more success rate the multiple node.

Held-constant factors

Factor	Description	Predict
Place	The size of experiment place is fixed.	None
Person in experiment room	There are 2 people in experiment room	None

Allowed to vary factors

Factor	Description	Predict
Wind	The experiment room is close room.	None
Light	When we proceed the experiment, the light is turning on.	None

Uncontrollable factors

Factor	Description	Predict
Wind	Wind can come from the movement from persons or breathe.	None
Electric noise interfere	Notebook, cell phone, router and etc.	Different channel of usage will have no effect to success rate.

Equipment

Equipment	Quantity
iDuino uno	3
Xbee pro s2 module	3
Xbee shield v1.1	3
Mini USB cable	3
Computer Laptop	3
Arduino IDE	1 per Laptop
XCTU program	1 per Laptop

Procedure

1. Connect Xbee to Xbee shield and attach them to iDuino uno board.
2. Repeat step 1 until getting 3 compositions.
3. Connect all compositions by mini usb cables to computer labtop.
4. Set switch mode on Xbee shield to left and right respectively from the top.
5. Run X-CTU program for setting role.
6. Select port and then press Test/Query
7. Displayed popup will appeared xbee information.
8. Press “Ok” and then select “Modem Configuration” Tab
9. Press “Read”
10. For each roles of nodes are set differently as step below
    a. Coordinator :
        i. set “modem” to “XBP24B47”
        ii. set “Function Set” to “Zigbee Coordinator API”
        iii. set “Version” to “21A7”
        iv. Press Show Defaults
        v. set networking, addressing and serial interface following these PAN ID = 1, SH = 0, SL = FFFF, API = 2
    b. Router :
        i. set “modem” to “XBP24B47”
        ii. set “Function Set” to “Zigbee Router API”
        iii. set “Version” to “23A7”

iv. Press Show Defaults
v. set networking, addressing and serial interface following these PAN ID = 1, SH = 00000000, SL = 00000000, JV = 1, API = 2

c. End Device :
i. set “modem” to “XBP24B47”
ii. set “Function Set” to “Zigbee Router API”
iii. set “Version” to “29A7”
iv. Press Show Defaults
v. set networking, addressing and serial interface following these PAN ID = 1, SH = 13A200, SL = 40982655, API = 2

11. Check box “Always Update Firmware” and press “Write”
12. First experiment test only 1 hop that consider only 2 nodes of coordinator and router
13. Set switch modes on all xbee shields to left and left for programming mode.
14. Open source code in Arduino IDE and burn each nodes with different programs. Starting with program that send payload data 5 bytes per round.
15. Set switch modes on all xbee shields to right and right for transmitting mode.
16. Open serial monitor in Ardino IDE by select Tool > Serial port > Select port.
17. Set distance between nodes to 20 meters
18. Press reset switch on all i-Duino uno boards
19. Record responses in replicate 1.
20. Repeat 18-19 again and record response in replicate 2
21. Repeat step 12 to 20 by changing these following
    a. Step 14: change payload data from 5 bytes to 10 bytes.
    b. After run finished, change payload data in step 14 to 15 bytes.
22. Repeat step 12 to 21 by changing these following
    a. step 17: change distance between nodes from 20 meters to 40 meters
    b. After run finished, change distance between nodes in step 17 to 80 meters
23. Repeat step 12 to 22 by changing hop number in step 12 from 1 hop to 2 hops that consider 3 nodes for coordinator, router, and end device.

Nested Design

Three Factor

The data collection was completely randomized and 2 replicates were obtained.

		Distance (m)								
		20 m			40 m			80 m		
		Data size (byte)			Data size (byte)			Data size (byte)		
		5 bytes	10 bytes	15 bytes	5 bytes	10 bytes	15 bytes	5 bytes	10 bytes	15 bytes
Number of nodes	2 nodes									
	3 nodes									

We design to use 3 stage nested design with 2 observations.

In minitab program, we assign data as following

Distance

Level 1	**20 m**
Level 2	40 m
Level 3	80 m

Number of Nodes

Level 1	**2 nodes**
Level 2	3 nodes

Data Size

Level 1	**5 byte**
Level 2	10 byte
Level 3	15 byte

3 stage nested design tree

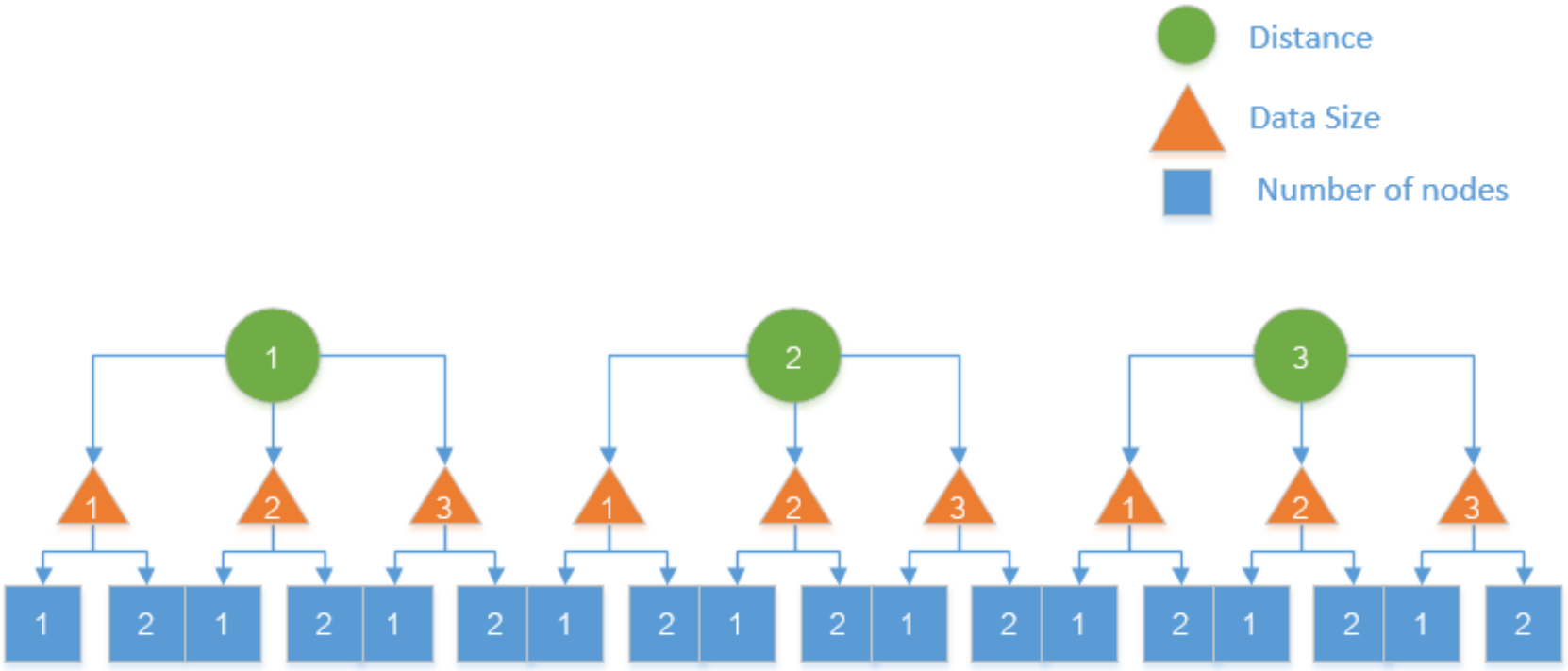


Figure 1Nested Tree

Experiment Design

After we run all the experiments of every factors and receive the responses with 2 replicates. Then we run in ANOVA test to find out what factor has significant effect.

Design with nested factor

Class Level Information		
Class	Levels	Values
Distance	3	1,2,3
Data Size	3	1,2,3
Nodes	2	1,2

Result from experiment

Distance	Data Size	Nodes	Response
1	1	1	100
1	2	1	70
1	3	1	70
2	1	1	60
2	2	1	90
2	3	1	80
3	1	1	60
3	2	1	70
3	3	1	60
1	1	1	70
1	2	1	80
1	3	1	90
2	1	1	70

2	2	1	70
2	3	1	70
3	1	1	60
3	2	1	80
3	3	1	70
1	1	2	80
1	2	2	70
1	3	2	80
2	1	2	90
2	2	2	80
2	3	2	70
3	1	2	70
3	2	2	80
3	3	2	80
1	1	2	90
1	2	2	90
1	3	2	80
2	1	2	80
2	2	2	80
2	3	2	50
3	1	2	60
3	2	2	70
3	3	2	60

Average success rate response = 74.444 %

Statistical Analysis

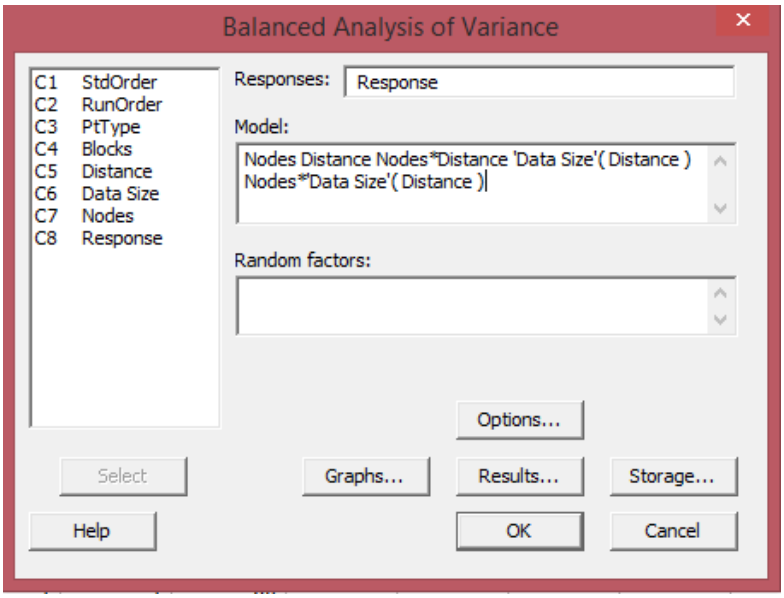
After collect all responses from experiment, then we use MINITAB statistic program to run statistical analysis.

First we assign the input to the program as following

StdOrder	RunOrder	PtType	Blocks	Distance	Data Size	Nodes	Response
1	1	1	1	1	1	1	100
2	2	1	1	1	2	1	70
3	3	1	1	1	3	1	70
4	4	1	1	2	1	1	60
5	5	1	1	2	2	1	90
6	6	1	1	2	3	1	80
7	7	1	1	3	1	1	60
8	8	1	1	3	2	1	70
9	9	1	1	3	3	1	60
10	10	1	1	1	1	1	70
11	11	1	1	1	2	1	80
12	12	1	1	1	3	1	90
13	13	1	1	2	1	1	70
14	14	1	1	2	2	1	70
15	15	1	1	2	3	1	70
16	16	1	1	3	1	1	60
17	17	1	1	3	2	1	80
18	18	1	1	3	3	1	70
19	19	1	1	1	1	2	80
20	20	1	1	1	2	2	70
21	21	1	1	1	3	2	80
22	22	1	1	2	1	2	90
23	23	1	1	2	2	2	80
24	24	1	1	2	3	2	70
25	25	1	1	3	1	2	70
26	26	1	1	3	2	2	80
27	27	1	1	3	3	2	80
28	28	1	1	1	1	2	90
29	29	1	1	1	2	2	90
30	30	1	1	1	3	2	80
31	31	1	1	2	1	2	80

32	32	1	1	2	2	2	80
33	33	1	1	2	3	2	50
34	34	1	1	3	1	2	60
35	35	1	1	3	2	2	70
36	36	1	1	3	3	2	60

Then select STAT > ANOVA > Balanced ANOVA



We find out the model (exact F-value) as

- Nodes
- Distance
- Nodes*Distance
- Data Size(Distance)
- Nodes*Data Size(Distance)

Then click OK

ANOVA: Response versus Nodes, Distance, Data Size

Factor	Type	Levels	Values
Nodes	fixed	2	1, 2
Distance	fixed	3	1, 2, 3
Data Size(Distance)	fixed	3	1, 2, 3

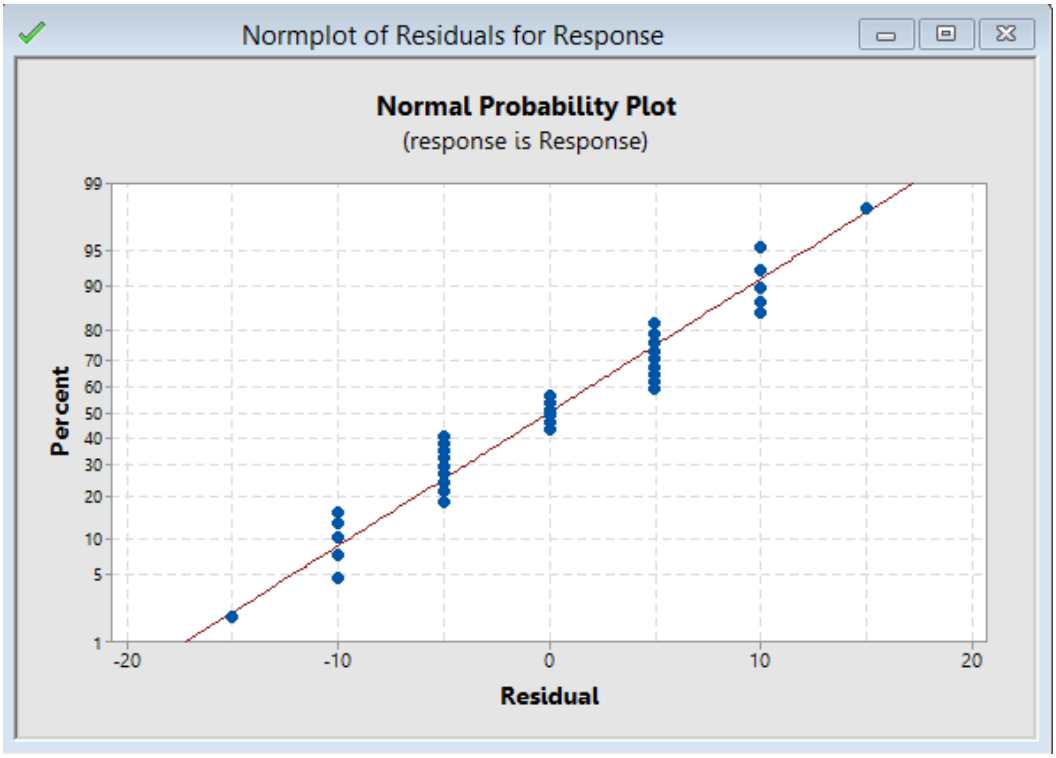
Analysis of Variance for Response

Source	DF	SS	MS	F	P
Nodes	1	44.4	44.4	0.42	0.525
Distance	2	938.9	469.4	4.45	0.027
Nodes*Distance	2	5.6	2.8	0.03	0.974
Data Size(Distance)	6	750.0	125.0	1.18	0.358
Nodes*Data Size(Distance)	6	650.0	108.3	1.03	0.440
Error	18	1900.0	105.6		
Total	35	4288.9			

S = 10.2740 R-Sq = 55.70% R-Sq(adj) = 13.86%

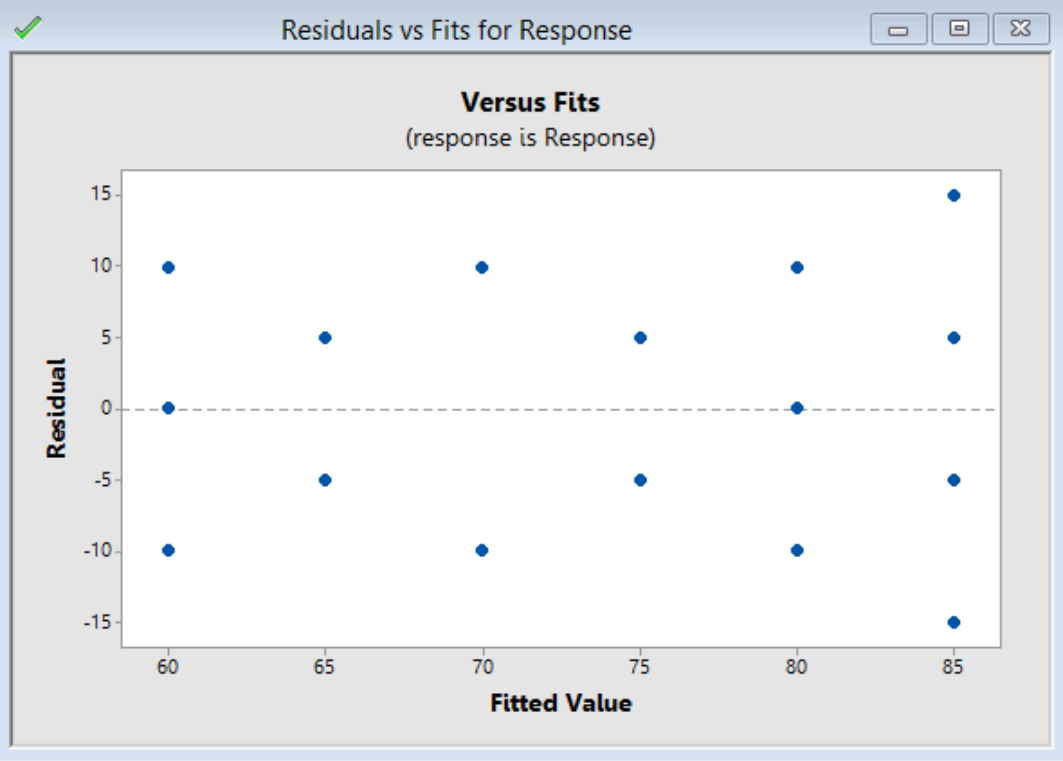
From the analyzed data above, we can see that Distance factor has significant effect to the response.

Normal Plot of Residuals for response



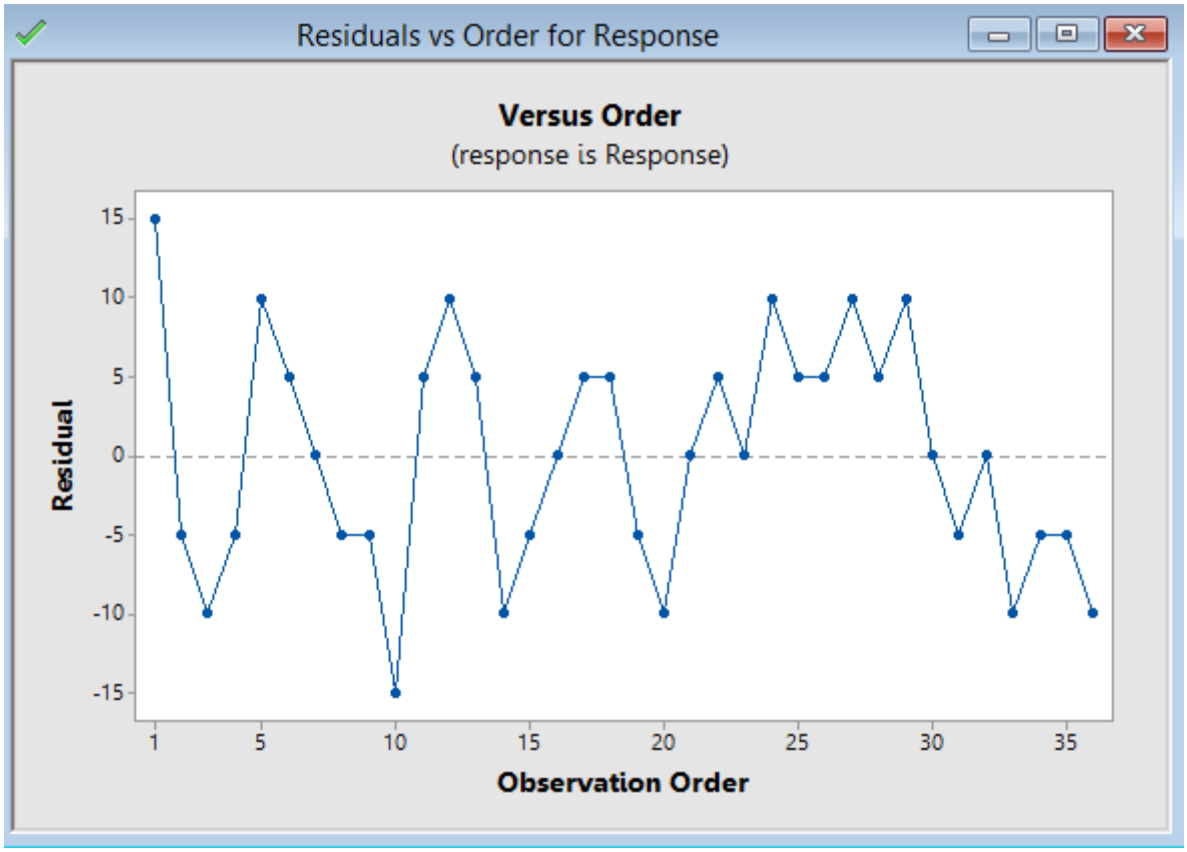
From the graph above, the residual plots fall along with the line. We can conclude that the model is usual.

Residual vs Fits



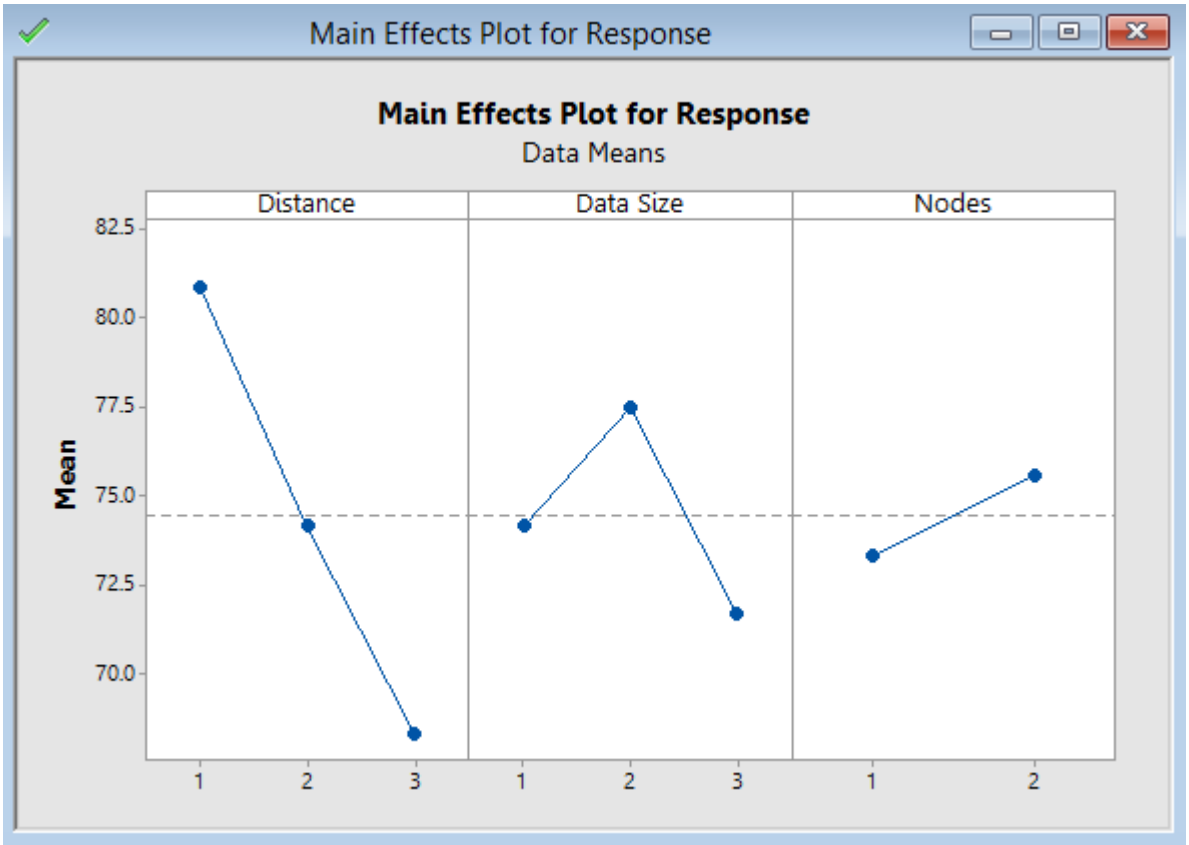
From the graph above, we can see that the residual plots are in random pattern. So, the model is satisfied.

Residual vs Order



From the graph above, we can see that the residual plots are in random pattern. So, the model is satisfied.

Main effects plot for response



From the graph above, we can see that Distance factor has the highest slope which means that its significant factor.

Conclusion from normal plot and main effect plot go along in the same way, which show that Distance is the significant factor.

Compare Analysis

Factor	Predicted Effect	Actual Effect
Distance	Low distance between nodes will have more success rate than the longer one.	Distance appears to have significant effect to success rate.
Data size	The data size should not significant affected to success/totalsend rate.	Data size have insignificant effect to success rate.
Nodes	Less nodes will have more success rate the multiple node.	Nodes have insignificant effect to success rate.

Conclusion

From datasheet information, in indoor place, maximum distance that data can be transmitted is estimated around 90 meters without interference and environment variant. In outdoor place, maximum distance that data can be transmitted is around 3200 meters without interference and environmental variant. That means transmission range capability is reduced if interference or environmental variant occur.

From the experiment, experimental room is quite no environmental variant such as strong wind, rain fall, etc. so the result show that the only factor can affect to the response is distance. Even if we add more node to route packet with the equal distance between nodes, any effect is not occurred. If concern about environmental variant is neglected, distance between nodes is important to consider.

It's clear to verify that our hypothesis and experimental result are corresponding. For practically, to design appropriately with the equal area, we recommend to reduce distance between node by using more than 2 nodes to route multihop that will be efficient more than single hop

Best case scenario to maximize response

Distance	**Data Size**	**Number of nodes**	**Response**
20 m	5 byte	2	90 %

References

1. **Xbee/XBee-Pro Zb RF Modules** [Online], Available : http://www.adafruit.com/datasheets/XBee%20ZB%20User%20Manual.pdf

2. Douglas C. Montgomery, 2013, **DESIGN AND ANALYSIS OF EXPERIMENTS EIGHTH DEITION,** John Wiley & Sons, Inc,. USA.