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Taguchi Approach for Recognizing the Most Influential Factor in Improving IEEE 802.15.4 Performance

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Abstract: WPAN using IEEE 802.15.4 protcol operated in non beaconing mode an attempt has made to find out the most significant factor of defacto parameters of IEEE 802.15.4 to enhance the performance by minimizing energy consumption and to enhance the network lifetime of the Wireless Personal Area Networks(WPAN). The factors include Buffer size, Beacon Interval, Back-off-transmission has an ideal impact on QoS metrics in IEEE 802.15.4 protocol. A Design of experiments have been simulated to an optimum level using the taguchi approach. The experimental results from the taguchi approach reveales that Back-of-transmission as the most significant factor for IEEE 802.15.4 in minimizing the power consumption in the WPAN.

Keywords: IEEE 802.15.4, Qos Metrics

I.INTRODUCTION

In the real world application Wireless Personal Area networks (WPAN) and Wireless Local Area Networks (WLAN's) are increasing rapidly to survive the means of global web connectivity. In Short range communication of WLAN's and WPAN's IEEE 802.15.4 plays a key role as low bit rate, less interference and low power consumption

The IEEE 802.15.4 plays a vital role in cross layer design approach which makes an connectivity between the MAC and Network layer. Until the connection establishment between the node is IEEE 802.15.4 upon the establishing the connectivity between the nodes is called ZigBee up to application layer. In Cross Layer Design approach consists of Logical Link Control (LLC) and Service Specific Convergence Sub-Layer (SSCS) to maintain low bit rate and low power consumption.

The IEEE 802.15.4 using the DSSS (Direct Sequence Spread Spectrum) modulation for non interfering of data. Implementing the two features will reduce the power consumption and the improves the network life time. The Channel allocation in MAC can be done in two ways

a. Beaconing Mode
b. Non-Beaconing Mode

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But in IEEE 802.15.4 use the Non-Beaconing Mode with the Un-slotted ALOHA. Implementation on Un-slotted ALOHA with respect to non specific time interval may leads to data collision and caused the data Grable leads to context of retransmission of data. In order to prevent the retransmission of data the CSMA/CD technique is used at MAC Sub layer.

II.LITERATURE REVIEW

Gezer, A et al [1] mentioned that WPAN using IEEE 802.15.4 protocol with defacto back of transmission the performance is limiting. They proposed a model ACAMRO which increases the throughput by 120% using the Buffer size 20KB. Choudary et al [2] have mentioned IEEE 802.15.4e is an amendment for Industrial Applications. A model constructed by Markova's for IEEE 802.15.4e using DSME and TSCH mode compared the performance with IEEE 802.15.4 Chew et al [3] IEEE 802.15.4 and Zigbee thread specific protocols for wireless IOT. They mentioned IEEE 802.15.4 is using physical and MAC Sub-layer where Zigbee(in the upper layers) using IEEE 802.15.4 from the bottom. Sonali et al [4] mentioned that IEEE 802.15.4 a basic for WPAN's at physical and MAC Sub-layers uses the protocols like Zigbee, Z-wave, Thread and HART.

Manikanta, P et al [5] mentioned that using the Taguchi approach to find out the most appropriate factor that suits for Mobile Adhoc network in DYMO routing protocol.

Rao, C.P.V.N.J.M. et al [6] identified Time to Live (TTL) as the most significant factor in STAR routing protocol by design of experiments conducted using Taguchi approach.

Sonkalitha et al [7] mentioned that low rate WPAN uses 802.15.4 protocol and here the performance of this protocol under slotted CSMA/CA in MAC layer. They designed the network with star topology and a PAN coordinator.

Al saif et al [8] mentioned that they consider three personal Area Networks and a PAN coordinator with mobility and analysed the performance.

III.IEEE 802.15.4 PROTOCOL

IEEE 802.15.4 protocol is designed for low rate personal area networks (PAN) which operate at for sensing (monitoring) and actuating (controlling) for enhancing of the network life time as IEEE 802.15.4 protocol being operated low date rate is promising feature of power minimization. Basically IEEE 802.15.4 protocol is operated at physical layer, MAC+LLC(Logical link Control) and SSCS(service specific convergence sublayer) and will be moved to upper layers

IEEE 802.15.4 protocol basically operated as ISM (Industrial, Scientific and Medical) using the DSSS(Direct sequence Spread Spectrum) Modulation. Using the DSSS the protocol is highly tolerant for noise and channel interference system. Using the same channel any multiple no of times can leads to the interference may cause the data collision and the loss of the data. Loosing of data may leads to the retransmission of data which causes data congestion in network and further increases of data collision. To resolve the data collision the concept of CSMA/CD is incorporated at the MAC Level. The IEEE 802.15.4 protocol is shown in Fig 1

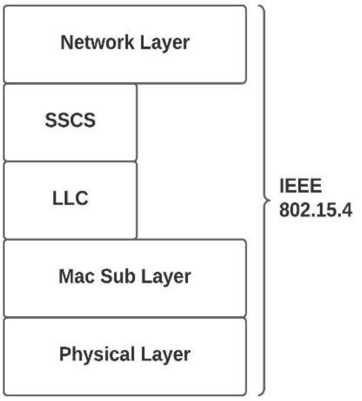

Figure 1 IEEE 802.15.4 Protocol

IEEE 802.15.4 Protocol is categorized into two categories basing upon the network channelization

a) Beaconing Network
b) Non- Beaconing Networks

Beaconing Networks uses the slotted ALOHA and Non-Beaconing Networks uses the un-slotted ALOHA but IEEE 802.15.4 protocol uses the non-beaconing networks. IEEE 802.15.4 is categorized to two categories basing on the Functionality

a) Fully Functioned Device (FFD)
b) Reduced Functioned Device (RFD)

FFD can interact with all devices and uses all protocols and RFD can only interact to FFD incorporates the low power consumption. IEEE 802.15.4 in a network beacon interval in connectivity to back of transmission plays a key role

IV.METHODOLOGY OF RESEARCH

4.1 Qualitative Research Methods:

Basically Qualitative approach consists of 3 methods and they are mathematical, Experimental and simulation. Among these approaches simulation is chosen because experimental approach consists of practical problems and mathematical approach is highly prohibitive. In order to implement IEEE 802.15.4 protocol three simulator is identified and they are Opnet, Cooja and Omnet++. Among the all cooja version 2.7 is chosen for a better graphical representation and various parameters can be identified for QoS metric. The research technique was to evaluate the finding, collecting analyzed and compare the data and draw conclusions from the observed results to determine significant element impacting performance improvement.

4.2 Quantative Research Method

This paper determine the most influential factor to improve the performance of IEEE 802.15.4 protocol to minimize the energy consumption and delay. In order to examine the most influential factor a design of experiments were conducted by taguchi method of approach. Taguchi method has run on the three factor with optimum level to identify the most significant factor among the set of three factors to minimize the energy consumption and delay.

4.3 Tool Used for simulation

Cooja is the simulation tool used which has a high range of adaptability to wireless sensor networks. Researchers can easily identify the influential factors and impact with respect to Wireless Networks. In research point of perspective

a) Design New Model for Existing Protocols
b) Compare study between new models and existing models
c) Analysis upon various QoS Metrics
d) Highly Adaptable to Real World Scenarios.

4.4 Simulation Setup

Cooja Simulator is used to run set of various scenarios using the IEEE 802.15.4 protocol of inputs have been considered for constructing various variety scenarios shown in Tab 1 and scenarios in Fig 2

Table 1 Simulation Parameter

Specifications	Values
Protocol	IEEE 802.15.4
Simulation Time	300 Sec
Area	100X100
Mote Type	Sky Mote
Propagation Model	UGDM
Tx Ratio, Rx Ratio	100%, 100%
Nodes	10, 20, 30
Topology	Eclipse
Traffic	Constant Bit Rate
Buffer Size	40000,50000,60000, 80000
Beacon (times)	1, 5
Back of Transmission	2,3,5,6

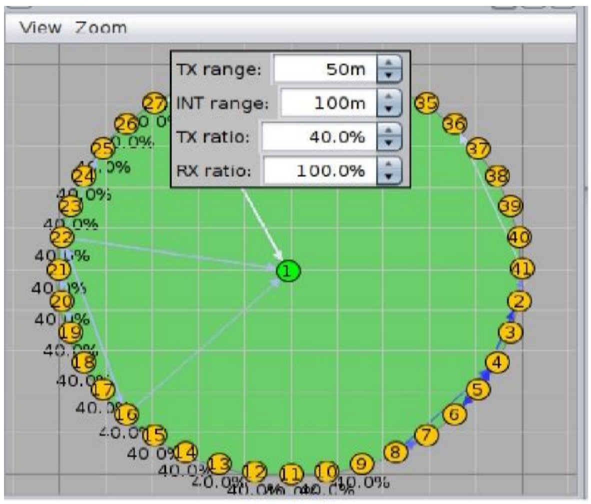

Figure 2 Simulation Scenario

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V.ANALYSIS AND FINDINGS

Using the simulator and conducting the experiments upon various scenarios with IEEE 802.15.4 protocol it is identified that buffer size, Beacon interval and Back-Off-transmission has a significant impact on power and delay. Here are using taguchi analysis identifying the most significant factor on optimum level and validated using the simulator show in Fig 3

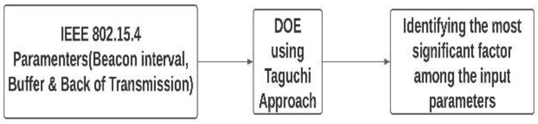

Figure 3 Block Diagram for Taguchi Approach

5.1 Taguchi Design

An orthogonal array of L_{32} (Mixed-Design) approach has been chosen with Back of Transmission, Buffer and Beacon Interval (time) with level 4,4,2 respectively shown in Tab 2

5.2 Orthogonal Array

An Orthogonal Array with 32 set of experiments at various combinations has been specified

L specifies LEVEL

Table 2 Mixed Design for Orthogonal Array

S.no	Factors	L1	L2	L3	L4
1	Back of Trans	2	3	5	6
2	Buffer Size	40000	50000	60000	80000
3	Beacon interval	1	5	*	*

An experiment 8 at Beacon interval at level 1, Buffer at level 2 and back off transmission at level 4 and power and delay shown at C4 and C5.

5.3 Analysis an Taguchi Approach

Table 3 Orthogonal Array L_{32}

Beacon	Buffer	Back of Transmission	Power	Delay
1	40000	2	1.271	0.962
1	40000	3	1.268	0.957
1	40000	5	1.223	0.952
1	40000	6	1.207	0.948
1	50000	2	1.241	0.975
1	50000	3	1.235	0.968
1	50000	5	1.207	0.962
1	50000	6	1.197	0.954
1	60000	2	1.257	0.984
1	60000	3	1.223	0.973
1	60000	5	1.187	0.962
1	60000	6	1.092	0.952
1	80000	2	1.252	0.907
1	80000	3	1.211	0.998
1	80000	5	1.102	0.976
1	80000	6	1.157	0.952
5	40000	2	1.231	0.961
5	40000	3	1.222	0.952
5	40000	5	1.207	0.948
5	40000	6	1.197	0.94
5	50000	2	1.224	0.963
5	50000	3	1.219	0.952
5	50000	5	1.217	0.947
5	50000	6	1.173	0.932
5	60000	2	1.275	0.972
5	60000	3	1.213	0.962
5	60000	5	1.205	0.957
5	60000	6	1.172	0.946
5	80000	2	1.213	0.958
5	80000	3	1.201	0.947
5	80000	5	1.187	0.945
5	80000	6	1.167	0.942

W.r.t C4 and C5 needs to find out the most significant factor

5.4 Flow Diagram

The flow diagram for finding out the most significant in taguchi approach is below in the Figure 4

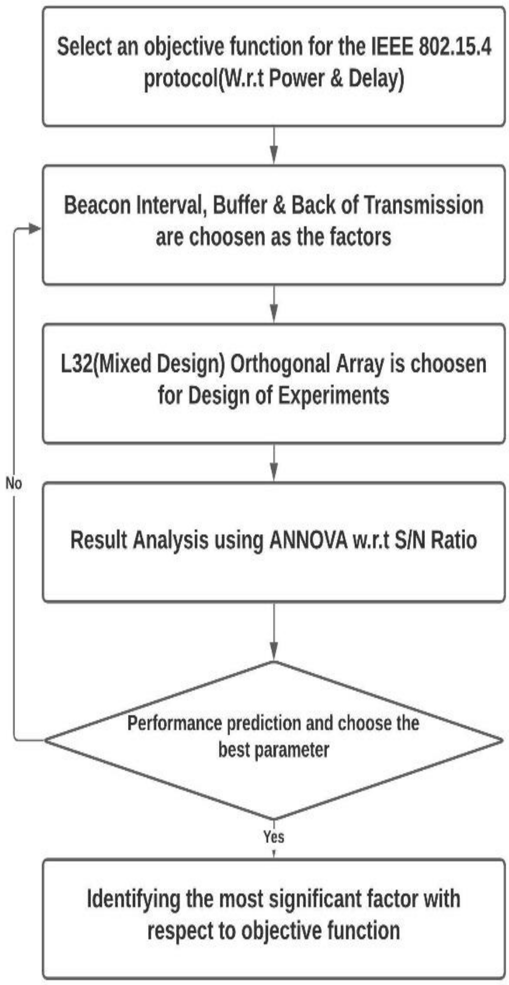

Figure 4 Flow Diagram to find the most significant value

5.5 Power

Power consumed by each node in a network over the lifetime. " Smaller is the Better considered".

Response Table

Response Table identifies the most significant factor from the set of factors. The factor with Delta rank having 1 is identified as the significant factor shown in Table 4

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Table 4 Response Table for Power

Response Table for Signal to Noise Ratios
Smaller is better

Level	BEACON INTERVAL TIMES	BUFFER	BACK OFF TRANSMISSIONS
1	-1.634	-1.784	-1.906
2	-1.637	-1.684	-1.755
3		-1.597	-1.521
4		-1.478	-1.362
Delta	0.003	0.306	0.544
Rank	3	2	1

Analysis of Variance

ANNOVA is a statistical method in identifying the significant factor and it consists of sum of squares and mean of the square with F and P Value shown in Table 5

Analysis of Variance for SN ratios

Table 5 Analysis of Variance

Source	DF	Seq SS	Adj SS	Adj MS	F	P
BEACON INTERVAL TIMES	1	0.00007	0.00007	0.000071	0.00	0.959
BUFFER	3	0.40534	0.40534	0.135114	5.27	0.023
BACK OFF TRANSMISSIONS	3	1.40216	1.40216	0.467388	18.24	0.000
BEACON INTERVAL TIMES*BUFFER	3	0.18807	0.18807	0.062689	2.45	0.131
BEACON INTERVAL TIMES* BACK OFF TRANSMISSIONS	3	0.17080	0.17080	0.056933	2.22	0.155
BUFFER*BACK OFF TRANSMISSIONS	9	0.41987	0.41987	0.046652	1.82	0.193
Residual Error	9	0.23063	0.23063	0.025625		
Total	31	2.81694				

Main affect Plots for SN Ratio

Main affect plots show the graphical visualization to find the significant factor and Main affect plots also shows that the Back off Transmission as the most influential factor shown in Figure 5

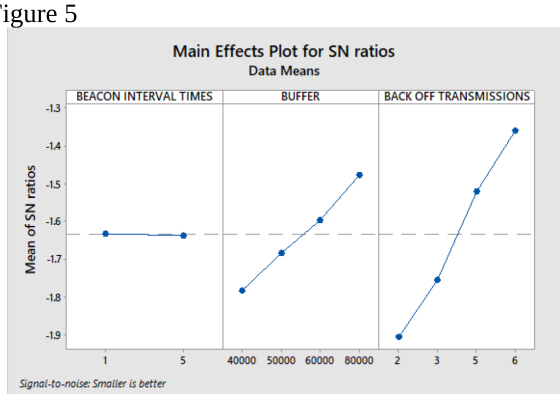

Figure 5 Power SN Ratios

5.6 Delay

Here delay is the end to end Delay to sink node to leaf node and the reverse.

Response Table

The Response table for delay also specifies the back of transmission as the most significant factor and response table is shown in the Table 6

Table 6 Response Table for Delay

Response Table for Signal to Noise Ratios
Smaller is better

Level	BEACON INTERVAL TIMES	BUFFER	BACK OFF TRANSMISSIONS
1	0.3439	0.4229	0.3546
2	0.4323	0.3859	0.3229
3		0.3236	0.3902
4		0.4199	0.4847
Delta	0.0884	0.0993	0.1618
Rank	3	2	1

Analysis of Variance

ANNOVA statistical method also specifies that Back off transmission as the most significant value in Table 7

Table 7 Analysis of Variance for Delay

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
BEACON INTERVAL TIMES	1	0.06250	0.06250	0.062502	3.10	0.112
BUFFER	3	0.05115	0.05115	0.017049	0.85	0.503
BACK OFF TRANSMISSIONS	3	0.11766	0.11766	0.039221	1.95	0.193
BEACON INTERVAL TIMES*BUFFER	3	0.01182	0.01182	0.003941	0.20	0.897
BEACON INTERVAL TIMES* BACK OFF TRANSMISSIONS	3	0.06819	0.06819	0.022729	1.13	0.388
BUFFER*BACK OFF TRANSMISSIONS	9	0.19045	0.19045	0.021161	1.05	0.471
Residual Error	9	0.18133	0.18133	0.020148		
Total	31	0.68310				

Main affect Plot for SN Ratio

The main affect plots of SN Ratio delay also specifies that back off transmission as the most significant value shown in the Figure 6

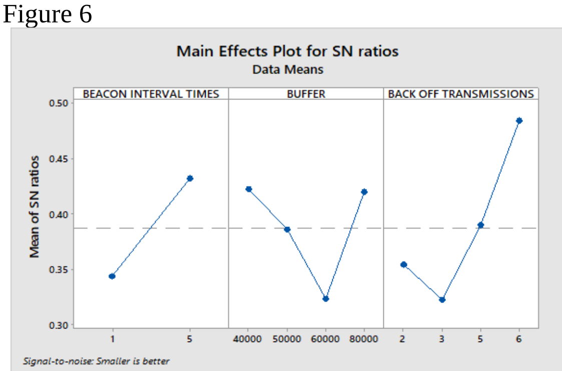

Figure 6 Delay SN Ratio

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VI. CONCLUSION AND FUTURE SCOPE

In this paper design of experiments were conducted basing on taguchi approach upto an optimum level on the buffer size, Beacon Interval(times) and Back of Transmission and drawn a conclusion that the Back off Transmission is the most significant factor. The Back off transmission shown an promising influence in the power conservation and limiting the delay between the nodes.

In contrast to the Back of Transmission be a static value and soft computing is applied in converting the back of transmission to a dynamic value.

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