ENERGY EFFICIENT DESIGN METHODOLOGY USING CONGESTION CONTROL PARAMETERS IN WIRELESS NETWORKS

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Abstract

Due to the rapid development of sensors in recent years, there has been a growing demand in wireless multimedia applications such as video surveillance, traffic monitoring and real time object tracking systems. So, there is a need to consider energy efficient design inorder to save power. The characteristics of WMSN lead to congestion occurrence that affects the performance of the network. To maintain the required QoS parameters for the specific applications, the factors that affect the performance of the network and its significance have to be identified. It is identified that, workload, traffic burstiness and routing protocol are considered to be the important factors which affect the important performance metrics video quality, reliability and latency. The important factors and their impact on the performance metrics are examined by design of experiments method. Based on the results, the network infra-structure requires very less consumption of power when transmitting data and also it improves quality of services (QoS).

Index terms: *Congestion control, wireless multimedia sensor networks, influencing factors, performance study*

1. Introduction

The Wireless Multimedia Sensor Networks can be described as a group of connected wireless sensors that collect multimedia data (i.e. audio and video) along with scalar data from the environment and transmit them to a base station (sink node). WMSNs introduce several challenges for energy-efficient multimedia processing and communication, primarily related to the delivery of high quality of service (QoS). To fulfill the QoS prerequisites for multimedia applications, a reliable transport protocol is needed. One of the principle destinations of the transport layer in WMSNs is congestion control.

It is seen that the data given may have different levels of significance and it is contended that sensor networks should be ought to spend more resources in spreading packets conveying vital data. In WMSN event-driven applications, it is important to report the detected events, resulting sudden bursts of traffic (due to the occurrence of spatially-correlated or multiple events). Packet losses and retransmissions due to congestion, cost precious energy and shorten the lifetime of sensor nodes. Till now, in WMSNs, Congestion control procedures depend on identification of congestion and recovery, yet they cannot eliminate or prevent the event of congestion. The use of sensor networks is not effective in different kinds of applications, owing to its characteristics includes power aware sensor nodes, dynamic topology, network link, data collection, scheduling, service detection, query handling, reliability and quality of service. It is not easy to change the batteries of sensor nodes when drained, hence it is critical to devise energy efficient algorithms and protocols[1]. Multimedia data transmission wants reliability due to its characteristics like huge size and data correlation. But the existing solutions concentrate on network efficiency, which are lenient of data loss, are not suitable for multimedia communication [2].

Hence protocols designed for WMSNs should be directed toward finding ways to preserve desirable characteristics such as network self-adaptation, scalability and fairness among competing traffic flows, while at the same time coping with the resource constrained nature of the underlying network as well as the time and bandwidth requirements posed by applications. [3]. Concerning the qualities of WMSNs, multimedia transfer produces bursty high-load movement in the system [4]. Consequently, likelihood of congestion in WMSNs is more and it causes waste of energy consumption. The congestion adversely influences reliability because of the packet losses and also corrupts the overall performance of the system and QoS of the applications. Congestion control is a complex job for wireless networks since recognizing the event of congestion is more difficult than in wired networks. In general, congestion control protocols for WSNs consider specific parameters such as local buffer occupancy, packet arrival rate, and packet service time. Conversely, deciding on the level of congestion based on a specific parameter may give incorrect results [5].

Application throughput needs may change when the sensing scenario changes and the amount of data that a WSN carries is subject to spontaneous changes. In wireless health and assisted living applications for example, the wireless sensors may be emitting a low rate of data when the person is in a healthy state. In this condition, monitoring only the heart rate and blood oxygenation may be sufficient. A typical data rate for this sensing scenario is four bytes per minute. However, if the person’s clinical condition changes it will be required to send a real time ECG. The data rate for this sensing scenario should be 750 bytes per second according to the long standing American Heart Association recommendation for ECG monitoring, which recommend digitization in a frequency of 500 Hz with a resolution of 12 bits.

Achieving higher video quality in base stations is an important objective in WMSNs. The main reason for low video quality in WMSN’s base station is bursty traffic which causes congestion in the network, and consequently a large number of lost packets. There are significant numbers of research efforts in solving the congestion problem of sensor networks by different congestion detection and rate adjustment techniques. Some applications require high packet delivery ratio and some other applications require delay sensitive data.

The upward trend in wireless communication caused researchers to envision and develop many congestion control protocols. However, it is often not clear which protocol should an application use for good video quality, higher reliability, lower delay or specific throughput demand. Because WMSN are deployed in remote areas, on bridges and building in hard to reach places, and are expected to operate with close to zero maintenance.

WMSN are likely to meet ambient and QoS conditions that will demand optimizing along more than one dimension. WMSN will meet an environment in which it will be wise to have both high reliability and high throughput, and some environments will offer opportunities to provide better video quality

WMSNs data will be in different forms like seasonal data reporting, constant information overseeing, event-driven data, query-based data, and vital command for sensor control. QoS characteristics such as delay, error rate, and throughput requested by these data patterns are different

To impart the required QoS for multimedia applications in WMSNs, congestion control is essential. All congestion control protocols should have the ability to detect congestion earlier, and suitably assign available rates to the sensor nodes. For some applications, it is required to send real time traffic toward the sink node with low latency and high reliability so that immediate remedial and defensive actions can be taken. Further, when a critical event occurs in the system, the sensor node which detects the event should send an alert message to the sink. Generally this sort of high priority traffic is bursty. This means that high priority traffic is generated only for a short period of time while low priority traffic usually exists in the network. For such environments, service differentiation in wireless multimedia sensor networks becomes a main problem. It is identified that the research in wireless multimedia networks is not focused in designing the transport protocol based on the requirement of the performance metrics of the specific applications. Instead of using a specific congestion factor, combination of multiple factors that includes work load, traffic shape (burstiness) and routing protocol is used for congestion control.

So in this study it is tried to optimize the network parameters for the given application requirements. The contributions of this paper are the following: a) To find the combination of different factors that cause congestion is introduced to get a more accurate measurement of the congestion. b) Propose a model to find the impact of the selected factors on the important performance metrics such as reliability, latency and video quality. c) Propose a protocol that provides specifications for the WMSN that suits the demand of the specific WMSN applications .

The rest of this paper is organized as follows: Related work section describes the works that are carried out in this domain. The Evaluation design section defines the system under study, the services provided by the system, the metrics, and the factors and their levels. Evaluation technique articulates how each response measure was obtained or calculated. The experimental Design section holds the data and results of the experiments conducted. Summarization of results and outline of a plan to proceed further is given in the Conclusions section.

2. Related Work

Some recent researches that are related to the proposed model are presented in this section. These works are fall into one of the following categories. Some works are related to congestion detection and control methods. Some others are related to congestion avoidance methods. Some of the wireless sensor networks congestion control approaches are adopted directly for some wireless multimedia sensor network applications. Other applications have used modified wireless sensor network congestion control methods.

In [6] a priority based congestion protocol (PCCP) is proposed which uses the ratio between packet inter arrival time and packet service time as the congestion indicator. Congestion control technique uses the above said metric along with node priority index. It is shown that PCCP achieves efficient congestion control and flexible fairness for both single path and multipath routing. Though it is proved as promising method, further analysis shown that it increases scheduling rate and source rate for all incoming traffics regardless of their priority in low congestion cases. Because of its inability of distinguishing different traffic classes.

To overcome the weakness of PCCP, in [7] a new approach is motivated. It considers diverse priorities for each node based on both the importance level of the incoming traffic and nodes geological need. It also adjusts the rate of source sending rate based on the nodes' congestion kevel. This resolves the problem of PCCP for low congestion conditions. It outperforms considerably than PCCP, but it has its own drawback like the transient characteristics of multimedia traffics i.e., traffic burstiness is not taken into account. An abrupt change in the incoming traffic rate is always assumed to lead congestion while this might not be true always. Some fuzzy based approaches are proposed to modify the rate adjustment mechanism to handle the shortages of the existing mechanisms.

In [8], a method is introduced by using two major units ie. Congestion control unit and fuzzy queue management unit. It is a strategy to control the nodes maximum transmission rate based on the weighted packet loss to resolve permanent changes in packet generation of the local traffic sources while leaving short term changes upto the queue management part. In [9], queue based congestion control protocols protocol with priority support (QCCP-PS) is proposed. It uses queue based congestion indicator to solve the problem of PCCP which performs poorly in providing relative priority in the case of random service time. It is done by adjusting the sending rate of each traffic source depending upon its congestion and its priority index. In [10] trust based fuzzy congestion controller, the misbehavior of the sensor nodes are identified using the concept of trust. It considers the impact of the network congestion due to the misbehavior of the faulty nodes and thereby minimizes their effect during packet transmission. Because of this, its performance is better than QCCP-PS. Prioritized Heterogeneous Traffic-oriented Congestion Control Protocol (PHTCCP) is an efficient congestion control protocol for handling diverse data with different priorities within a single node motivates. PHTCCP module works interacting with the MAC layer to perform congestion control function. Congestion could be controlled by ensuring adjustment transmission rates for different type of data that generated by the sensors have various priorities [11].

The congestion control framework for WMSN was suggested in [12], give the needed bandwidth and to mitigate the congestion problem in multimedia applications. The congestion control mechanism was implemented on the top of multipath routing facility. In order to maintain the quality of video streaming, the congestion control mechanism based on load repartitioning over the multiple paths was suggested. The load repartition based congestion control (LRCC) uses queue length as congestion detection indicator along with collision rate. LRCC also uses explicit congestion notification by using special control messages (called congestion notification messages). In reception of these notification messages, the source node will try to balance its traffic on the available paths while reducing the amount of data sent on the current congested path in order to reduce the congestion.

It is trusted that the new characteristics and constraints due to the multimedia content handling, the WSNs routing protocols are not directly applicable for WMSNs. The multimedia nature of the collected information (video streaming, still images, audio) adds more constraints on the design of the routing protocols in order to meet the application-specific QoS requirements and network conditions. The routing protocol performs path optimization to optimize the routing paths with least number of nodes. In order to perform path optimization, each node is put into three states: active and available, active but unavailable and dead. The paths/routes/links between the nodes is put into two states: available and unavailable. The routes are chosen in such a way that it lies on the top of active and available nodes and available links to eliminate the holes and to optimize the routing paths with minimum number of hops. TPGF [13] Multimedia-aware Multipath Multi-Speed (Multimedia-aware MMSPEED) routing protocol is proposed in [14]. Multimedia-aware MMSPEED is an extension over MMSPEED routing protocol. It considers the embedded information in the received packets in which near optimum path is reserved for I-packets and marginal paths are used for P-frames.

In the literature, it is realized that the proposed protocols for wireless multimedia sensor network have different methodologies. The proposed protocols lie under different categories as follows, where the first class shows the routing protocols based on ant colony optimization. The ACO displays several features that make it particularly suitable for wireless multimedia sensor networks. The second class is geographic routing protocols like TPGF and GPSR. These protocols achieve good performance and it is suitable for WMSN as it ensures uniform energy consumption and meets the delay and packet loss constraint. The last class of the proposed protocols follows different algorithm types and addresses different QoS metrics that are required for multimedia transmission with resource constraint nature of WMSN.

3. Evaluation Design

Analysis of experiments helps in separating out the effects of various factors that might affect the performance [15]. Also it allows determining if a factor has a significant effect or if the observed difference is simply due to random variations caused by measurement errors and parameters that were not controlled. The system which is going to be studied is described. And also metrics used to study the systems behavior (response) is articulated. A concise explanation and characteristics of the factors that can affect are given.

3.1 System Definition

The purpose of the study is to gain the knowledge of which factors affect the performance the congestion control protocols in wireless multimedia sensor networks. The objective is to design congestion control protocols in wireless multimedia sensor networks, where several choices have to be made to suit the for the different WMSN applications requirements.

3.2 Problem statement:

Study the impact of the three important factors ie work load, traffic burstiness and routing technique on the performance of wireless multimedia sensor networks measured in terms of peak signal to noise ratio(PSNR), Packet Delivery Ratio(PDR) and Delay.

3.3 Factors

This section explains the factors that are used in experimental design and analysis. Among the several factors that affect the system performance metrics, the three important factors are taken. They are: Work load, Traffic burstiness and Routing Protocol.

i.Work load factor.

The work load factor is characterized by data rate, buffer size, available bandwidth, number of traffic source nodes and mobility of nodes. The two levels of work load, workload -1 and workload -2 are defined as follows.

Work load 1 : available bandwidth:50 Mbps, data rate:1000 kbits/sec, buffer size:10, number of traffic source nodes:2

Work load 2 :available bandwidth:600 Mbps, data rate:3000 kbits/sec, buffer size:80, number of traffic source nodes:15

ii.Traffic burstiness factor

At different times, applications need to transfer different amount of data. Most of the wireless multimedia sensor network applications generate only bursty traffic. That is for some duration of the period there is no data traffic and another point of time there will be a sudden rise in the data traffic. This is because of sudden events that occur in real time multimedia applications. We define the bursty-1 as constant data flow of 3 Mbps and bursty-2 as abrupt variation from 0 to 100 Mbps. The two levels of traffic burstiness bursty-1 and bursty-2 is depicted in the Fig. 1. In order to define the level of burstiness for the experiments, the bandwidth for a node allocated by the network is taken as 3 Mbps. In Fig.3.1, the sensor node sends a burst of data at a rate of 12 Mbps for 3 seconds, for a total of 36 Mb of data. The sensor node (host) is silent for 5 seconds and then sends data at a rate of 2 Mbps for 3 seconds, for a total of 6 Mb of data. In all, the host has sent 42 Mb of data in 11seconds.

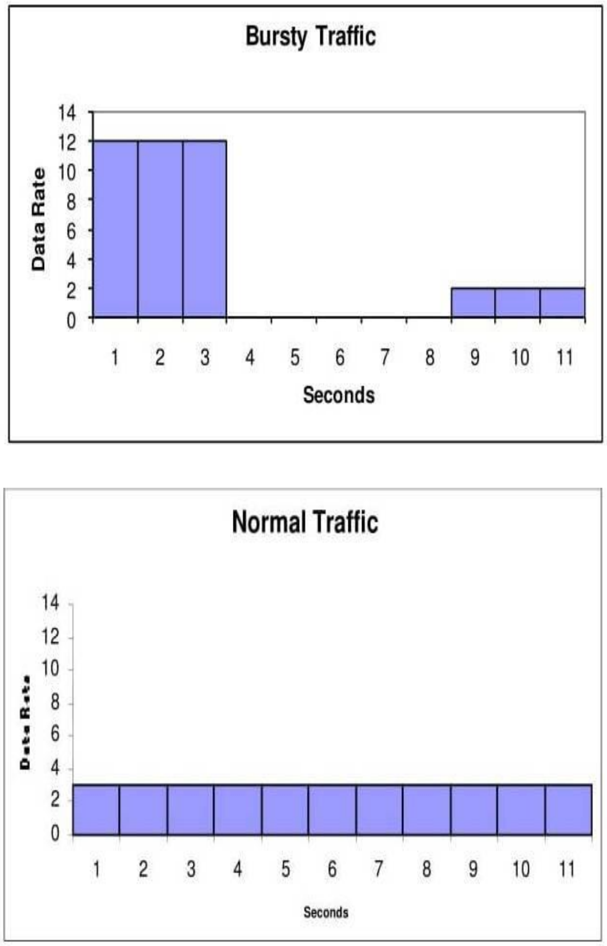


Fig 3.1. Traffic Burstiness (a) Bursty 1 and (b) Bursty 2

iii.Routing Protocol choice factor

The WMSN routing protocols ASAR and MMSPEED are selected as routing protocol 1 and routing protocol 2 respectively. The difference in the approach (logic) that those two protocols take will provide for an interesting study. The three factors and their levels are summarized Table 3.1.

Factor	Level -1 Description	Value	Level -1 Description	Value
Work Load, A	Work Load 1	50 Mbps	Work Load 2	600 Mbps
Routing Protocol, B	Routing Protocol 1	ASAR	Routing Protocol 2	MMSPEED
Burstiness , C	Burstiness 1	Constant flow of 3 mbps	Burstiness 2	Rapid variation from 0 to 100 Mbps

Table 3.1: Factors and their levels

4. Evaluation Technique

The effect that the three factors specified in the above have on the following response variables Peak Signal to Noise Ratio, Packet Delivery Ratio and Latency are evaluated.

Peak signal-to-noise ratio (PSNR): the video quality is evaluated in terms of the average peak signal to-noise ratio (PSNR) of the received video. PSNR is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation. The **PSNR** is usually expressed in terms of the logarithmic decibel scale.PSNR is defined mathematically as

$$PSNR = 10 \log10 (MAX_I{}^2/MSE) \quad (Eq.4.1)$$

where MAX_I is the maximum possible pixel value for each frame. MSE is the mean squared error, which is defined as

$$MSE = (1/mn)(\sum_1^{m-1}\sum_1^{n-1} \| I(i,j)-K(i,j) \|^2) \quad (Eq.4.2)$$

for any two mxn images I and K where one of the images can be considered to be a noisy approximation of the other. To extend this to video distortion rather than image distortion, we take the PSNR measurement for each frame and average over all of the frames in the video. The MSE represents the average of the squares of the "errors" between our actual image and our noisy image. The error is the amount by which the values of the original image differ from the degraded image. For color images, the MSE is taken over all pixels values of each individual channel and is averaged with the number of color channels.

The Peak Signal to Noise Ratio (PSNR) measured in dB at the receiver side is listed in table 4.1.

Work Load (Mbps)	Routing Protocol 1		Routing Protocol 2	
	Bursty1	Bursty 2	Bursty 1	Bursty 2
Work Load 1	66	47	78	65
Work Load 2	60	39	72	58

Table 4.1 PSNR Study of a 2^3 experiment

Reliability is a key factor for the performance of any routing protocol. Reliability requirement is the required probability of any packet reaching its destination. **Reliability** is calculated by the ratio called PDR (Packet Delivery Ratio). PDR is the ratio of the number of transmitted packets to the number of acknowledged packets. Each PDR value is calculated over 10 seconds time window:

$$PDR = \#packets\ received\ /\ \#packets\ sent \quad (Eq.4.3)$$

The packet delivery ratio (PDR) is listed in table 4.2.

Work Load (Mbps)	Routing Protocol 1		Routing Protocol 2	
	Bursty1	Bursty 2	Bursty 1	Bursty 2
Work Load 1	0.65	0.55	0.68	0.58
Work Load 2	0.55	0.45	0.61	0.43

Table 4.2 PDR Study of a 2^3 experiment

Latency: The latency (delay) metric measures the time to transmit and receive a packet from sender to receiver. The latency is derived from the queuing delay, processing delay, propagation delay, and transmission delay. Let TS be the time a sender sends the packet and TR be the time when a receiver received the packet, then:

$$\text{Latency} = TR - TS \qquad \text{(Eq.4.4)}$$

The Latency in msec. is listed in table 4.3.

Work Load (Mbps)	Routing Protocol 1		Routing Protocol 2	
	Bursty1	Bursty 2	Bursty 1	Bursty 2
Work Load 1	30	58	28	56
Work Load 2	52	82	50	75

Table 4.3 Latency Study of a 2^3 experiment

5. Experimental design

Design of experiments (DOE) is a systematic method to determine the relationship between factors affecting a process and the output of that process. In other words, it is used to find cause-and-effect relationships. $\mathbf{2^k r}$ factorial design is used for experimental design to determine the effect of k factors, each of which has two alternatives of level. In this study k=3 and r=3. This model is easy to analyze and helps in sorting out factors in the order of impact and to estimate errors. Experimental errors can be quantified by repeating the measurements under the same factor level combinations.

5.1 2^3 3 factorial design with replications

$\mathbf{2^3\,3}$ factorial design with replications is used when there are three factors each at two levels and to isolate experimental errors. Each of the eight experiments is repeated r times. The performance y can now be regressed on xA, xB and xC using non linear regression model of the form

$$y=q_0+q_Ax_A+q_Bx_B+q_Cx_C+q_{AB}x_Ax_B+q_{BC}x_Bx_C+q_{AC}x_Ax_C+q_{ABC}x_Ax_Bx_C+e \qquad \text{(Eq.5.1)}$$

Here, e is the experimental error and q's are the effects

5.2 Computation of effects

For a 2^3 3 design, the effects can be computed easily by preparing a 8x8 sign matrix as shown in table 5.1. The first column of the matrix is labeled I, and it consists of all 1's. The next three columns, titled A , B and C, contain basically all combinations of -1 and +1. The next successive 4 columns are the product of the entries in the respective labeled columns.

The system experiments were repeated three times each. This results in the 24 observations shown in column y in tables 5.1, 5.2 and 5.3. The analysis is also known in the table. To get the sample mean y, sum the individual observations and divide by 3 (the number of replications). The entries in each of the eight columns are multiplied by those in column y and the sum is entered under the column. The sums under each column are divided by 8 to give the effects q0, qa, qb, qc, qab, qac, qbc & qabc. A sign table for the factors (Effects) and all interactions is prepared. The three measured responses y_i1, y_i2, and y_i3 are reported in the table 5.1. and then mean yi is calculated.

5.3 Estimation of experimental errors:

Once the effects have been computed in a 2^3 3 design, the model can be used to estimate the response for any given factor values(x- values) as follows:

$$\hat{y}_i=q_0+q_Ax_{Ai}+q_Bx_{Bi}+q_Cx_{Ci}+q_{AB}x_{Ai}x_{Bi}+q_{BC}x_{Bi}x_{Ci}+q_{AC}x_{Ai}x_{Ci}+q_{ABC}x_{Ai}x_{Bi}x_{Ci} \qquad \text{(Eq.5.2)}$$

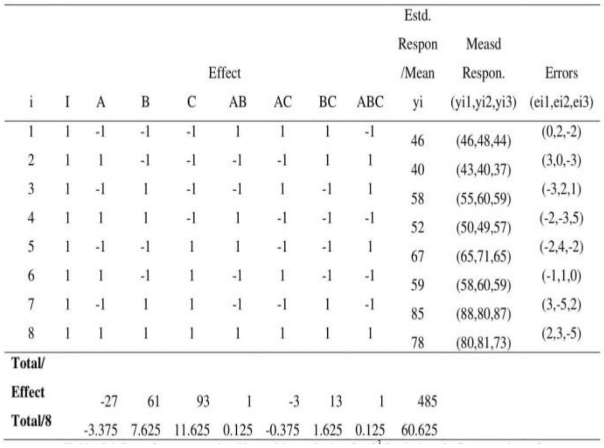
Here, $\hat{y}_i$ is the estimated response when the factors A,B and C are at levels x_{Ai}, x_{Bi} and x_{Ci} respectively. The difference between the estimate and the measured value y_{ij} in the j^{th} replication of the i^{th} experiment represents the experimental errors:

$$e_{ij}=y_{ij}-\hat{y}_i=y_{ij}-q_0-q_Ax_{Ai}-q_Bx_{Bi}-q_Cx_{Ci}-q_{AB}x_{Ai}x_{Bi}-q_{BC}x_{Bi}x_{Ci}-q_{AC}x_{Ai}x_{Ci}-q_{ABC}x_{Ai}x_{Bi}x_{Ci} \qquad \text{(Eq.5.3)}$$

We can compute the error in each of the 2^3 3 observations. The sum of the errors must be zero. The sum of the squared errors (SSE) can be used to estimate the variance of the errors and also to compute the confidence intervals for the effects:

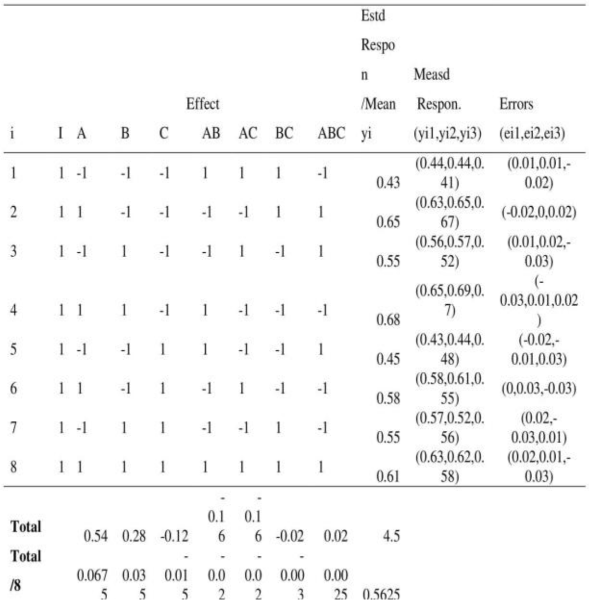
$$SSE= \sum_{i=1}^{2^2}\sum_{j=1}^{r} e_{ij}^{2} \qquad \text{(Eq.5.4)}$$

The Sign table analysis of a $2^3 3$ design and the Computation of errors are illustrated in tables 5.1, 5.2 and 5.3.



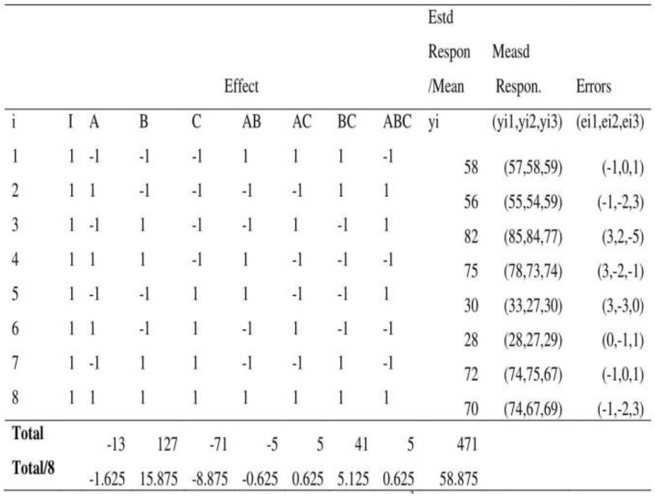
					Effect				Estd. Respon /Mean	Measd Respon.	Errors
i	I	A	B	C	AB	AC	BC	ABC	yi	(yi1,yi2,yi3)	(ei1,ei2,ei3)
1	1	-1	-1	-1	1	1	1	-1	46	(46,48,44)	(0,2,-2)
2	1	1	-1	-1	-1	-1	1	1	40	(43,40,37)	(3,0,-3)
3	1	-1	1	-1	-1	1	-1	1	58	(55,60,59)	(-3,2,1)
4	1	1	1	-1	1	-1	-1	-1	52	(50,49,57)	(-2,-3,5)
5	1	-1	-1	1	1	-1	-1	1	67	(65,71,65)	(-2,4,-2)
6	1	1	-1	1	-1	1	-1	-1	59	(58,60,59)	(-1,1,0)
7	1	-1	1	1	-1	-1	1	-1	85	(88,80,87)	(3,-5,2)
8	1	1	1	1	1	1	1	1	78	(80,81,73)	(2,3,-5)
Total/ Effect		-27	61	93	1	-3	13	1	485		
Total/8		-3.375	7.625	11.625	0.125	-0.375	1.625	0.125	60.625		

Table 5.1 Data for psnr study (Sign table analysis of a $2^3 3$ design & Computation of errors)



					Effect				Estd Respon /Mean	Measd Respon.	Errors
i	I	A	B	C	AB	AC	BC	ABC	yi	(yi1,yi2,yi3)	(ei1,ei2,ei3)
1	1	-1	-1	-1	1	1	1	-1	0.43	(0.44,0.44,0.41)	(0.01,0.01,-0.02)
2	1	1	-1	-1	-1	-1	1	1	0.65	(0.63,0.65,0.67)	(-0.02,0,0.02)
3	1	-1	1	-1	-1	1	-1	1	0.55	(0.56,0.57,0.52)	(0.01,0.02,-0.03)
4	1	1	1	-1	1	-1	-1	-1	0.68	(0.65,0.69,0.7)	(-0.03,0.01,0.02)
5	1	-1	-1	1	1	-1	-1	1	0.45	(0.43,0.44,0.48)	(-0.02,-0.01,0.03)
6	1	1	-1	1	-1	1	-1	-1	0.58	(0.58,0.61,0.55)	(0,0.03,-0.03)
7	1	-1	1	1	-1	-1	1	-1	0.55	(0.57,0.52,0.56)	(0.02,-0.03,0.01)
8	1	1	1	1	1	1	1	1	0.61	(0.63,0.62,0.58)	(0.02,0.01,-0.03)
Total		0.54	0.28	-0.12	-0.16	-0.16	-0.02	0.02	4.5		
Total /8		0.0675	0.035	-0.015	-0.02	-0.02	-0.003	0.0025	0.5625		

Table 5.2 Data for pdr study (Sign table analysis of a $2^3 3$ design & Computation of errors)



					Effect				Estd Respon /Mean	Measd Respon.	Errors
i	I	A	B	C	AB	AC	BC	ABC	yi	(yi1,yi2,yi3)	(ei1,ei2,ei3)
1	1	-1	-1	-1	1	1	1	-1	58	(57,58,59)	(-1,0,1)
2	1	1	-1	-1	-1	-1	1	1	56	(55,54,59)	(-1,-2,3)
3	1	-1	1	-1	-1	1	-1	1	82	(85,84,77)	(3,2,-5)
4	1	1	1	-1	1	-1	-1	-1	75	(78,73,74)	(3,-2,-1)
5	1	-1	-1	1	1	-1	-1	1	30	(33,27,30)	(3,-3,0)
6	1	1	-1	1	-1	1	-1	-1	28	(28,27,29)	(0,-1,1)
7	1	-1	1	1	-1	-1	1	-1	72	(74,75,67)	(-1,0,1)
8	1	1	1	1	1	1	1	1	70	(74,67,69)	(-1,-2,3)
Total		-13	127	-71	-5	5	41	5	471		
Total/8		-1.625	15.875	-8.875	-0.625	0.625	5.125	0.625	58.875		

Table 5.3 Data for delay study (Sign table analysis of a $2^3 3$ design & Computation of errors)

5.4Allocation of variation

The percentage of variation explained by each factor is helpful in deciding whether a factor has a significant impact on the response. The variation due to experimental errors can also be isolated since we have multiple observations for each factor level combination. The total variation or Total Sum of Squares (SST) is given by

$$SST= \sum_{i,j}\left(y_{ij} - \bar{y}_{..}\right)^2$$

$$= \sum_{i,j} y_{ij}^2 - \sum_{i,j} \bar{y}_{..}^{2}$$

$$= SSY-SS0 \qquad \text{(Eq.5.5)}$$

Here, SS0 represents the sum of squares of the mean.

Here $\bar{y}_{..}$ denotes the mean of responses from all experiments. The dots in the subscript indicate the dimension along which the averaging is done. Thus, $\bar{y}_{i.}$ denotes the means of responses in all replications of the ith experiment and $\bar{y}_{.j}$ denotes the mean of responses in the jth replication of all experiments. The SST can be divided into several parts as follows:

$$SST=SSA+SSB+SSC+SSAB+SSBC+SSAC+SSABC+SSE \qquad \text{(Eq.5.6)}$$

Where each SS(sum of square) corresponds to the variations explained the factors and interactions respectively. The SSE is the unexplained variation attributed to the experimental errors.

5.5 Confidence interval for effects

The standard deviation of errors is

$$se=sqrt(SSE/2^k(r-1)) \quad \text{(Eq.5.7)}$$

and the standard deviation of effects is

$$sqi=se/sqrt(2^k r). \quad \text{(Eq.5.8)}$$

The confidence intervals for the effects are

$$q_i \pm t_{[1-\alpha/2;2^3(r-1)]} s_{qi} \quad \text{(Eq.5.9)}$$

The t-value is read at $2^3(r-1)$ degrees of freedom (which is degrees of freedom associated with the experimental errors). For our case it is 16(since r=3). The t-value at 16 degrees of freedom and 90% confidence is 1.337. Any effect whose confidence interval does not include a zero is significant. The percentage of variation explained by the factors and the confidence intervals for the parameters are calculated using the equation with confidence interval are shown in the tables 5.4, 5,5 and 5.6.

5.6. Result and Discussion

Table 5.4 Effects and variation explained on psnr study

factor	**Effect on PSNR**	**Sum of Squares value**	**Variation explained (%)**psnr	**Confidence Interval**
a	-3.38	273.38	5.2984	(-2.1796,-4.57)
b	7.63	1395.4	27.044	(8.8204,6.4296)
c	11.6	3243.4	62.861	(12.82,10.43)
ab	0.13	0.375	0.0073	(1.3204,-1.07)
ac	-0.38	3.375	0.0654	(0.8204,-1.57)
bc	1.63	63.375	1.2283	(2.8204,0.4296)
abc	0.13	0.375	0.0073	(1.3204,-1.07)
errors		180	3.4886	

Table 5.5 Effects and variation explained on pdr study

factor	**Effect on PDR**	**Sum of Squares value**	**Variation explained (%)**	**Confidence Interval**
a	0.0675	0.1094	62.899	(0.0765,0.0585)
b	0.035	0.0294	16.911	(0.044,0.026)
c	-0.015	0.0054	3.1061	(-0.006,-0.024)
ab	-0.02	0.0096	5.522	(-0.011,-0.029)
ac	-0.02	0.0096	5.522	(-0.011,-0.029)
bc	-0.0025	0.0002	0.0863	(0.0065,-0.011)
abc	0.0025	0.0002	0.0863	(0.0115,-0.006)
errors		0.0102	5.867127	

Table 5.6 Effects and variation explained on latency study

factor	**Effect on Delay**	**Sum of Squares value**	**Variation explained (%)**	**Confidence Interval**
a	-1.625	63.375	0.719139	(-0.5265,-2.7235)
b	15.875	6048.375	68.63307	(16.9735,14.7765)
c	-8.875	1890.375	21.45076	(-7.7765,-9.9735)
ab	-0.625	9.375	0.106381	(0.473501,-1.7235)
ac	0.625	9.375	0.106381	(1.723501,-0.4735)
bc	5.125	630.375	7.15309	(6.223501,4.026499)
abc	0.625	9.375	0.106381	(1.723501,-0.4735)
errors		152	1.724798	

The percentage of variation explained by each factor on PSNR study, PDR study and Latency study are plotted in the Fig 5.1, Fig 5.2 and Fig 5.3 respectively. In fig 5.1 and 5.2 , the representation are a -workload factor , b -routing protocol, c - traffic burstiness , ab -workload factor & routing protocol , ac -workload factor& traffic burstiness , bc -routing protocol& traffic burstiness , abc-workload factor, routing protocol& traffic burstiness

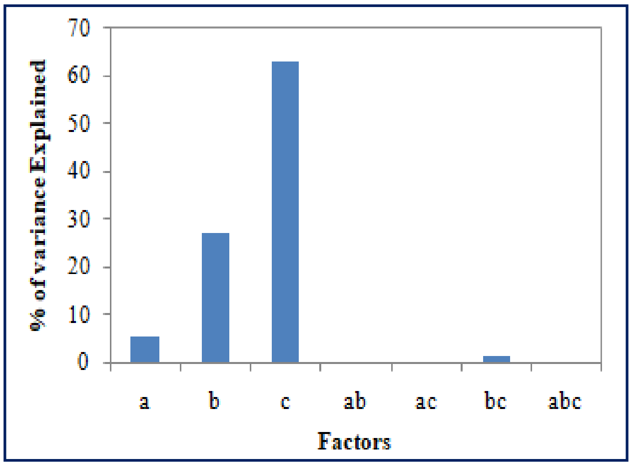


Fig 5.1 % of Variation Explained on PSNR Study

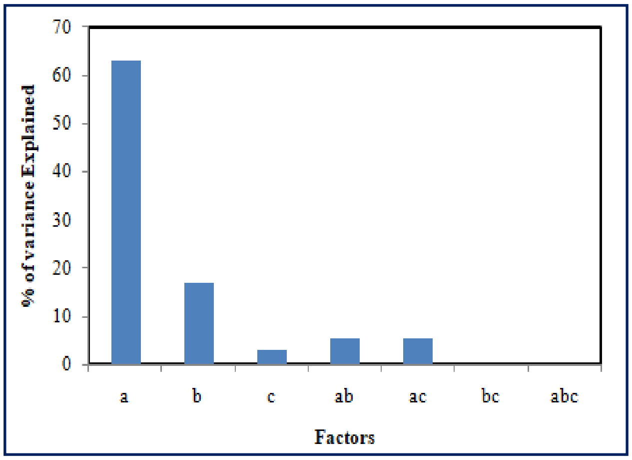


Fig 5.2 % of Variation Explained on PDR Study

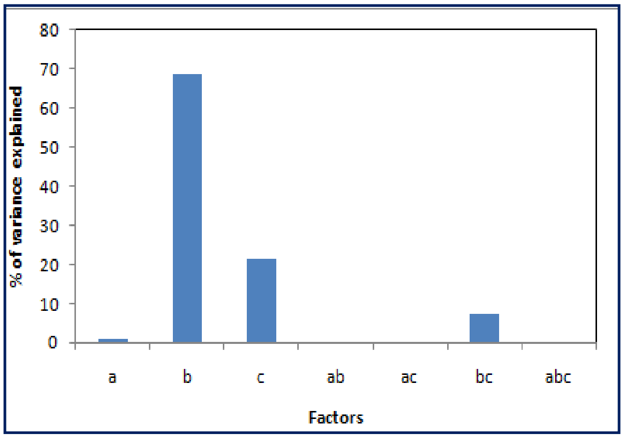


Fig 5.3 % of Variation Explained on Latency Study

From the analysis it is observed that the quality of the multimedia (PSNR) is highly influenced by the factor c(traffic burstiness), the packet delivery ratio(PDR) is mostly affected by the factor a (workload) and the latency is mostly affected by the factor b (routing protocol). It is also evident that all other factors(and the combination of the factors) effect on PSNR, PDR and Latency are not significant. Confidence intervals shown in the tables also conclude that these factors are significant.

6. Conclusion

There are certain characteristics of wireless sensor networking applications that have complex inter-relationships. In order to develop a network to support real-world applications, all of the characteristics must be taken into account and systematically optimized to work together in harmony. If the network size grows high, there will be a higher usage of available bandwidth. It implies less amount of bandwidth left for application data transmission. The mobility of the nodes is often in the network, which increase the responsiveness. To achieve high responsiveness, the network should issue and exchange more control packets, which will naturally reduce reliability results. It is evident from the obtained result that reliability is mostly affected by workload parameter. The main reason for getting low video quality is bursty traffic in MSN. The high bursty traffic suddenly increase the network traffic which results in high congestion and also the large no of packet drops. The obtained result shows that the video quality is mostly affected by traffic burstiness. The routing protocol selects optimal path to meet the desired QoS for different types of services. Latency is highly influenced by the routing protocol. Because all the routing protocols which are designed specifically for multimedia sensor network tries to reduce latency. This is confirmed by the obtained result. This framework provides the performance metrics (reliability, video quality and latency) and its most influencing factors (workload, traffic burstiness and routing protocol). From this, new protocols can be designed by choosing the appropriate factor(s) to meet out the performance demand for the specific applications in WMSNs.

In future, some more performance metrics and their influencing factors can be taken and analyzed to provide suggestion in designing of transport protocols for evolving multimedia applications.

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