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A Mathematical Model for Assigning the Priority for Incoming Packets in Event driven Applications for Wireless Sensor Network

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Abstract

Data gathering by the sensor is most important task in Wireless Sensor Networks (WSN) application like healthcare and security. In that to provide a Quality of Service (QoS) is major challenges due to processing a non-important packet prior to the import or critical packet. So that performance of the node is reduced and critical data is affected in the application. In this paper a priority based mathematical model is used to attain the QoS by assigning a various priority level for incoming packets. High level priority is given to the most critical data, least priority for Ordinary packets. So that the Critical data will be processed soon for data sensitive application.

Keywords: Wireless Sensor Networks, Quality of service, Priority, Critical Data

1. Introduction.

Recent advances has pushed the technology to its edge by introduction to Wireless Sensor Network (WSNs) systems due to breakthrough in fields of wireless communication and a vast field of sensor networks. Wireless sensor network has a unique functional property that allows it to operate at low energy consumption which eventually cuts out the costings. Hence, our main focus mainly on the application of industrial sector using WSNs. In United States, around two third of the energy in an industrial sector is consumed due motor driven systems or rather sensors. As the cost of energy increases, energy saving aspects by industrial associates are being pulled upon greatly. Therefore, in order to keep a watch on energy utilization an efficient energy consumption evaluator has introduced in the form of WSNs[1-3]. The main use of WSNs is to give an eye to potentially hazardous sites where human manpower cannot play a role, especially in an industrial sector. Such WSNs must be highly accurate while taking the readings as well as it should a high reliable design before it is being deployed in an actual environment. This paper organised into the following section

1. Introduction,
2. Related work,
3. Proposed model,
4. Conclusion.

2. Related work.

S-MAC and T-MAC puts nodes into periodic sleep to deal the problem of idle listening so that reduce the energy consumption by forming the virtual cluster to execute the common periodic sleep [4-5]. Some of the MAC protocol achieved energy efficient and QoS by giving the various priorities are listed. This protocol is widely considered for having less wastage of energy that is Wise-mac protocol. Wise-MAC uses a feature called preamble to minimize the energy consumption [6]. If the preamble is determined each and every time it leads to lot of wastage of energy, hence the length is predefined. All the preambles used are fixed size in length. This protocol suffers a disadvantage that is when it disperses various schedules to various nodes the schedules generated are not synced but then it also holds an advantage of having better performance result than S-MAC.DB-MAC: [7] It works with the principle of contention based and designed for delay bounded applications. It uses two types of priority. Give high priority to the node close to source by initializing PrMAX and for every node intermediate node crossing the value is reduced by one, that is PrMAX-1 and low priority to the nodes close to the receiver.Q-MAC: [8]These are designed to minimize energy consumption by setting the various traffic types and putting each traffic type into different levels of priority queues. It works on the principle of intra-node scheduling to select the next serviced packet from five different priority queues. Two factors determining the priority of an incoming packet are: content of the packet and traversed hop count. Inter node communication is takes places. The inter node communication mainly deals with the energy consumption by reducing the collision using the PC-MACAW protocol. It uses 00,01,10,11, two additional bits to identify the different types of priority.SIFT: [9] This protocol is considered when there are many nodes in the network and the ultimate aim is to send the packet from source to destination as soon as possible. The working is quite primitive and similar to S-MAC due to which many assume that it is a part of S-MAC. The advantage this protocol holds is less latency but the total energy consumption remains high caused by idle listening. Adding to this high overhearing also enhances the energy consumption. Implementation of MAC QoS in general most of the MAC protocol is used to minimize the energy by expanding the high data delivery latency, like f-MAC protocol is reduced the delay but fail to reduce the energy to overcome that it uses the TDMA based MAC protocol by modifying IEEE802.15.4 frame format to achieve the QoS [11].

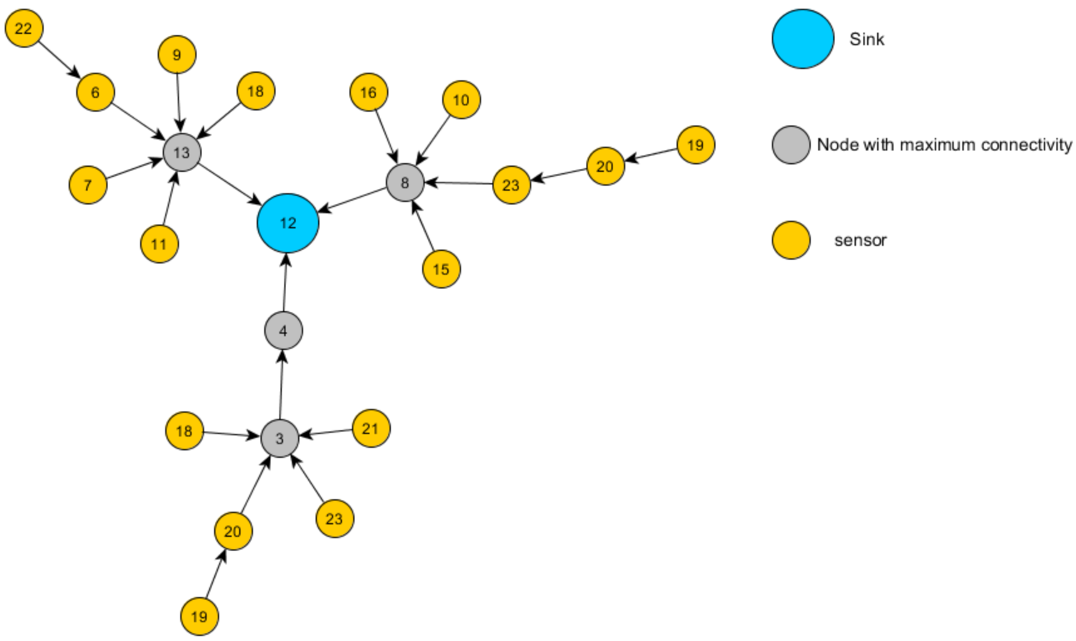

Figure 1: Structure of Sensor Network

Figure 1 show the general structure of Sensor Network,Figure 2: defines the various priority levels of the incoming packet.

Figure 2: Priority Queue

3. A Batch Arrival Mathematical Model for assigning priority.

The proposed model may applicable in mathematically in the field of Operation Research, particularly in Queueing models. Queueing system is a powerful tool for modelling communication networks, transportation networks, production lines and operating systems. In recent years, computer networksand data communication systems are the fastest growingtechnologies, which have led to significant development in applications such as swift advance in internet, audio data traffic, video data traffic, etc.

3.1 Model Description:

We consider the batch arrival retrial queueing system with priority customers, where the server applies a waiting space of infinite capacity[12-13]. The detailed description of the model is given as follows,

The arrival Process:
Customers arrive in batches according to a compound Poisson process with rate λ. Let X_k denote the number of customers belonging to the k^{th} arrival batch, where X_k, k = 1, 2, 3…are with a common distribution $\Pr[X_k = n] = \chi_n$, n = 1, 2, 3….

The retrial process:
We assume that there is no waiting space and therefore if an arriving batch finds the server free, one of the customers from the batch begins his service and rest of them join into orbit. Otherwise, the arriving customer joins the waiting space (called priority queue) with probability p or enters the retrial group (called orbit) with probability q, where $p + q = 1$. A new arriving customer who obtains service immediately is regarded as a member of the priority queue. We will assume that only the customer at the head of the orbit is allowed access to the server. If the server is busy upon retrial, the customer joins the end of the orbit again. Such a process is repeated until the customer finds the server idle and gets the requested service at the time of a retrial. Inter-retrial times have an arbitrary distribution $R(t)$ with corresponding Laplace-Stieltijes Transform (LST) $R^*(x)$.

The service process:
There is a single server who provides service to all customers. After completion of a service, the customer at the head of the priority queue (if any) is being served immediately. Otherwise, a possible new arrival and the one (if any) at the head of the orbit queue compete for service. According to the above rule, customers in the priority queue have non-preemptive priority over those in the orbit. The service times are independently and identically distributed with probability distribution function $S(t)$, Laplace-Stieltjes transform $S^*(x)$.

The inter-arrival times, retrial times and service times are mutually independent of each other.

3.2 Analysis of the steady state probabilities.
In this section, we first develop the steady state equations for the retrial system by treating the elapsed retrial times and the elapsed service times as supplementary variables. Then we derive the probability generating function (PGF) for the server states, the PGF for number of customers in the system and orbit.

The steady state equations single Queue
In steady state, we assume that $R(0)=0$, $R(\infty)=1$, $S(0)=0$ and $S(\infty)=1$ are continuous at $x=0$. So, that the function $a(x)$ and $\mu(x)$ are the conditional completion rates for retrial and service respectively. $a(x)dx = \frac{dR(x)}{1-R(x)}$ and $\mu(x)dx = \frac{dS(x)}{1-S(x)}$. In addition, let $R^0(t)$ and $S^0(t)$ be the elapsed retrial times and elapsed service times respectively at time t. Further, introduce the random variable[12][13],

We also note that the states of the system at time t can be described by the bivariate Markov process $C(t), N_1(t), N_2(t); t \geq 0$ where $C(t)$ denotes the server state (0 and 1) depending on the server is idle and busy. $N_1(t)$ and $N_2(t)$denotes the number of customers in the priority queue and in the orbit. If $C(t) = 0$, then $R^0(t)$represent the elapsed retrial time, if $C(t) = 1$, then $S^0(t)$corresponding to the elapsed time of the customer being served.

For the process, we define the probabilities $P_0(t) = P\ C(t) = 0,\ N_1(t) = 0,\ N_2(t) = 0$ and the probability densities.

$$P_{0,n_2}(x,t)dx \ = P\ C(t) = 0, N_1(t) = 0,\ N_2(t) = n_2,\ x \leq R^0(t) < x + dx\ , \text{for } t \geq 0,\ x \geq 0 \text{ and } n \geq 1,$$

$$\Pi_{n_1,n_2}(x,t)dx\ = P\ C(t) = 1, N_1(t) = n_1,\ N_2(t) = n_1,\ x \leq S^0(t) < x + dx\ , \text{ for } t \geq 0,\ x \geq 0 \text{ and } n \geq 0,$$

The following probabilities are used in sequent sections:

$P_0(t)$is the probability that the system is empty at time t.

$P_{0,n_2}(x,t)$ is the probability that at time t there are exactly n customers in the orbit and no customer in the priority queue with the elapsed retrial time of the test customer undergoing retrial is x.

$\Pi_{n_1,n_2}(x,t)$ is the probability that at time t there are exactly n customers in the priority queue and n customers in the orbit with the elapsed service time of the test customer undergoing service is x.

We assume that the stability condition is fulfilled and so that we can set for $t \geq 0$, $x \geq 0$ and $n \geq 1$.

$$P_0 = \lim_{t\to\infty} P_0(t),\ P_{0,n_2}(x) = \lim_{t\to\infty} P_{0,n_2}(x,t) \text{ and } \Pi_{n_1,n_2}(x) = \lim_{t\to\infty} \Pi_{n_1,n_2}(x,t).$$

Following the routine procedure of the method of supplementary variable technique, we obtain the following system of equations that govern the dynamics of the system behavior.

$$\lambda P_0 = \int_0^\infty \Pi_{0,0}(x)\mu(x)dx \tag{1}$$

$$\frac{dP_{0,n_2}(x)}{dx} + [\lambda + a(x)]P_{0,n_2}(x) = 0,\ n_2 \geq 1 \tag{2}$$

$$\frac{d\Pi_{n_1,n_2}(x)}{dx} + [\lambda + \mu(x)]\Pi_{n_1,n_2}(x) = \lambda p \sum_{k=1}^{n} \chi_k \Pi_{n_1-k,n_2}(x) + \lambda q \sum_{k=1}^{n} \chi_k \Pi_{n_1,n_2-k}(x),\ n_1, n_2 \geq 1. \tag{3}$$

The steady state boundary conditions at $x = 0$ are

$$P_{0,n_2}(0) = \int_0^\infty \Pi_{0,n_2}(x)\mu(x)dx,\ n_2 \geq 1 \tag{4}$$

$$\Pi_{0,n_2}(0) = \int_0^\infty P_{0,n_2+1}(x)a(x)dx + \lambda \int_0^\infty P_{0,n_2}(x)dx, \quad n_2 \geq 1, \tag{5}$$

$$\Pi_{n_1,n_2}(0) = \int_0^\infty \Pi_{n_1+1,n_2}(x)\mu(x)dx, \quad (n_1, n_2) \geq 1, \tag{6}$$

The normalizing condition is

$$P_0 + \sum_{n_2=1}^{\infty} \int_0^\infty P_{0,n_2}(x)dx + \sum_{n_1=0}^{\infty} \sum_{n_2=0}^{\infty} \int_0^\infty \Pi_{n_1,n_2}(x)dx = 1 \tag{7}$$

A steady state equation for multi Queue.

We also note that the states of the system at time t can be described by the bivariate Markov process $C(t), N_1(t), N_2(t), N_3(t); t \geq 0$ where $C(t)$ denotes the server state (0 and 1) depending on the server is idle and busy. $N_1(t)$, $N_2(t)$ and $N_3(t)$denotes the number of customers in the high priority queue, medium priority queue and in the orbit. If $C(t)$ = 0, then $R^0(t)$represent the elapsed retrial time, if $C(t)$ = 1, then $S^0(t)$corresponding to the elapsed time of the customer being served.

For the process, we define the probabilities $P_0(t) = P\ C(t) = 0,\ N_1(t) = N_2(t) = N_3(t) = 0$ and the probability densities

$$P_{0,n_2,n_3}(x,t)dx \ = P\ C(t) = 0, N_1(t) = 0,\ N_2(t) = 0 \text{ and } N_3(t) = n_2,\ x \leq R^0(t) < x + dx\ , \text{ for } t \geq 0,\ x \geq 0 \text{ and } n \geq 1,$$

$$\Pi_{n_1,n_2,n_3}(x,t)dx \ = P\ C(t) = 1, N_1(t) = n_1, N_2(t) = n_2 \text{ and } N_3(t) = n_3,\ x \leq S^0(t) < x + dx\ , \text{ for } t \geq 0,\ x \geq 0 \text{ and } n \geq 0,$$

The following probabilities are used in sequent sections:

$P_0(t)$is the probability that the system is empty at time t.

$P_{0,n_2,n_3}(x,t)$ is the probability that at time t there are exactly n customers in the orbit, no customer in the high priority queue and medium priority queue with the elapsed retrial time of the test customer undergoing retrial is x.

$\Pi_{n_1,n_2,n_3}(x,t)$ is the probability that at time t there are exactly n customers in the high priority queue, in the medium priority queue and n customers in the orbit with the elapsed service time of the test customer undergoing service is x.

We assume that the stability condition is fulfilled and so that we can set for $t \geq 0$, $x \geq 0$ and $n \geq 1$.

$$P_0 = \lim_{t\to\infty} P_0(t),\ P_{0,n_1,n_2}(x) = \lim_{t\to\infty} P_{0,n_1,n_2}(x,t) \text{ and } \Pi_{n_1,n_2,n_3}(x) = \lim_{t\to\infty} \Pi_{n_1,n_2,n_3}(x,t).$$

Following the routine procedure of the method of supplementary variable technique, we obtain the following system of equations that govern the dynamics of the system behavior.

$$\lambda P_0 = \int_0^\infty \Pi_{0,0,0}(x)\mu(x)dx \tag{8}$$

$$\frac{dP_{0,n_1,n_2}(x)}{dx} + [\lambda + a(x)]P_{0,n_1,n_2}(x) = 0,\ n_1, n_2 \geq 1 \tag{9}$$

$$\begin{aligned}\frac{d\Pi_{n_1,n_2,n_3}(x)}{dx} + [\lambda + \mu(x)]\Pi_{n_1,n_2,n_3}(x) &= \lambda p\sum_{k=1}^{n}\chi_k\Pi_{n_1-k,n_2,n_3}(x) + \lambda q\sum_{k=1}^{n}\chi_k\Pi_{n_1,n_2-k,n_3}(x)\\ &+ \lambda r\sum_{k=1}^{n}\chi_k\Pi_{n_1,n_2,n_3-k}(x),\ n_1, n_2, n_3 \geq 1.\end{aligned} \tag{10}$$

The steady state boundary conditions at $x = 0$ are

$$P_{0,0,n_3}(0) = \int_0^\infty \Pi_{0,0,n_3}(x)\mu(x)dx,\ n_3 \geq 1 \tag{11}$$

$$\Pi_{0,0,n_3}(0) = \int_0^\infty P_{0,0,n_3+1}(x)a(x)dx + \lambda\int_0^\infty P_{0,0,n_2}(x)dx,\ \ (n_1 = n_2 = 0 \text{ and } n_3 \geq 1) \tag{12}$$

$$\Pi_{0,n_2,n_3}(0) = \int_0^\infty \Pi_{0,n_2+1,n_3}(x)\mu(x)dx + \lambda q\int_0^\infty \Pi_{0,0,n_3}(x)dx\ \ (n_1 = 0 \text{ and } n_2, n_3 \geq 1) \tag{13}$$

$$\Pi_{n_1,n_2,n_3}(0) = \int_0^\infty \Pi_{n_1+1,n_2,n_3}(x)\mu(x)dx + \lambda p\int_0^\infty \Pi_{0,n_2,n_3}(x)dx,\ \ (n_1, n_2, n_3) \geq 1, \tag{14}$$

The normalizing condition is

$$P_0 + \sum_{n_3=1}^{\infty}\int_0^\infty P_{0,0,n_3}(x)dx + \sum_{n_1=0}^{\infty}\sum_{n_2=0}^{\infty}\sum_{n_3=0}^{\infty}\int_0^\infty \Pi_{n_1,n_2,n_3}(x)dx = 1 \tag{15}$$

Solve the above equations (1)-(7) and (8-15) get the standard results like probability that the server is idle P_0, the mean number of customers in the orbit L_o, the mean number of customers in the priority queue L_p, probability that server is idle during retrial time (P) and busy (Π) respectively. Without loss of generality, we assume that the retrial times and service times are exponentially distributed with the parameters a and μ.

Results.

From figures (1) and (2), we can conclude the followings, If we fix the retrial rate and service rate, then arrival rate (λ) increases, the probability that server is idle P_0 decreases, the mean orbit size L_q increases.

From figures (3) and (4), we can get the following results, ifwe fix the retrial rate, arrival rate and service rate, then the priority probability (p) increases, then the probability that server is idle P_0 decreases, the mean number of customers in the priority queue L_p increases.

From the results of the above priority model, we can reduce the idle time for the connected and high strength packets.

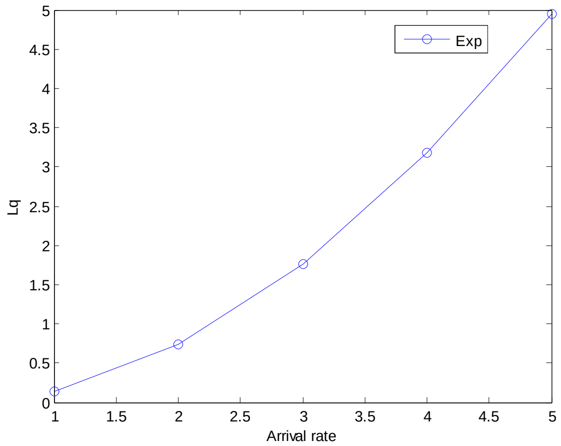

Figure 1: L_q versus λ

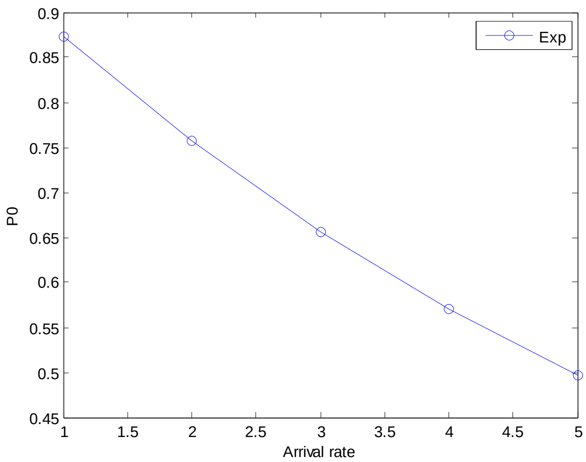

Figure 2: P_0 versus λ

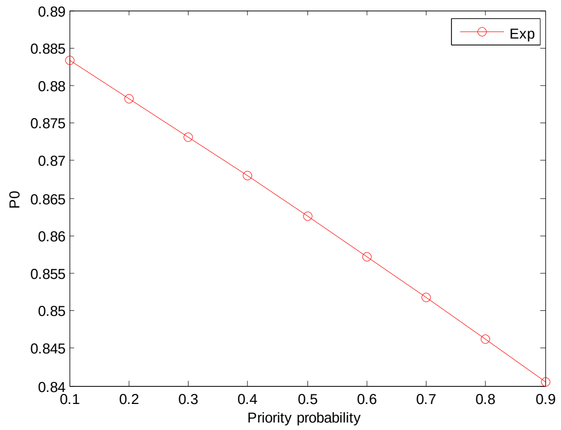

Figure 3: P_0 versus p

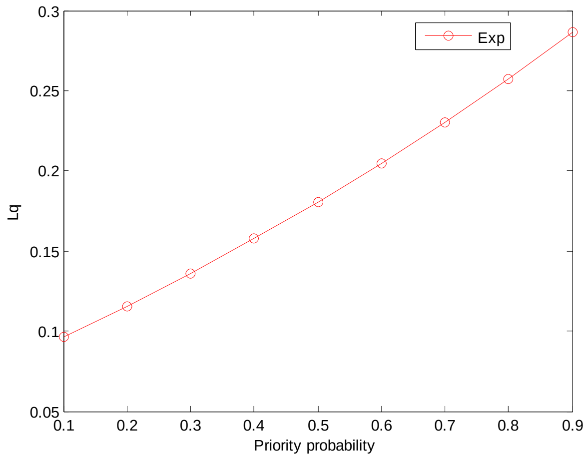

Figure 4: L_q versus p

4. Conclusion.

In this paper a Batch arrival mathematical model is used for our Event driven applications to prioritize the non-periodic data for assigning a various priority level for incoming packets based on the nature of the packets to attain the QoS in WSN application in MAC protocols. So first discussed about the current trends and application in wireless Sensor Network and various priority based MAC protocols are used in some of the applications, at last a mathematical model using batch arrival priorityqueue is used for our application to develop our own MAC protocols.

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