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Effective Scheduling and Queuing Strategy in WMSNs Using Enhanced Equivalent Capacity Model

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Abstract
Providing QoS to Wireless Multimedia Sensor Networks (WMSNs), is tough whose principle qualities are network congestion and link failures. A systematic packet planning can enhance the quality of delivery over sensor networks in these conditions. A new packet planning methodology for multipath data movement over WMSNs is introduced here. This method plans movement of variable packets over variable paths. As a result high preference packets are moved through high preference paths after doing timely checks on condition of path. WMSNs are capable of sensing multimedia data that need more bandwidth compared to Wireless Sensor Networks (WSNs). Available methods of WSN do not challenge multimedia applications. So bandwidth is a major challenge in WMSNs. Proposed novel approach using Gaussian bound is used to compute the effective bandwidth using frame traffic.

Keywords: *WMSNs WSN, QoS, TCP, UDP, Medium access control, M/M/1 queue*

1. Introduction

Wireless transmission has been recognized as easy and cost-effective. It requires low maintenance to give convenient end to end capabilities on data trading in many occasions. Voice calls of analog type in 70's is an example that shows the advancements and changes wireless networks have seen to present top speed consistent and effective data transmission.

Wireless Sensor Networks (WSNs), in recent years, has acquired researcher's awareness due to its usage in various actual circumstances. Habitually, cost and size of a single sensor node limits the application domain. This results in restricting the resources (memory, CPU) in sensor node. The newest variants of Wireless Multimedia Sensor Networks (WMSN's) are a result cost reduction of hardware like microphones and CMOS cameras. Capturing and transmitting audio and video streams in WMSNs is possible by sensor nodes upon wireless channel. WMSNs are complex but still possess fewer utilities in comparison to ordinary sensor nodes.

WSNs and WMSNs are used in collecting and communicating data everywhere to target nodes. To obtain correct functionality of such networks desired communication protocol plays a vital role. Conventional architecture requires fewer resources in wireless communication medium like TCP/IP protocol stack in WSNs. Performance of TCP in wireless communication is poor as per reports as it is TCP protocol was primarily designed for wired networks. Flow and congestion control mechanisms make TCP unfit for multimedia flows. For multimedia applications, rather than TCP, UDP is an alternate choice but it won't give feedback on condition of the network that can help in correct movement of interactive media data. Hence, WMSNs are not compatible with both TCP and UDP transport layer protocols.

There exist numerous usages that importantly aid the users from WMSNs. Surveillance and tracking utilities with regards to, military, health care, and agriculture etc. is the area these networks are more relevant. Research on efficient making of these applications is a necessary aspect due to increase in various safety and terrorism warnings to people and lucrative assets. However, resource lacking sensor networks face a task due to the type and amount of information gained in these applications. A protocol that incorporates service bi-furcation to reach end to end communication is needed in surveillance applications with heterogeneous traffic flows. Prioritized medium access according to traffic nature based on the applications is provided by Medium Access Control (MAC) [10].

A dynamic packet scheduling scheme deploys the nodes in a hierarchical system virtually so that each node has three stages of preference queues except nodes located at the last level. Preference node routes the image packets to its destination according to packets. Recently, the requirements of bandwidth for multimedia integrated services and actual information transmission is an important aspect. For effective bandwidth of multimedia traffic, reliable computation is required.

The transmission capacity of a connection is called bandwidth and is an important feature to determine the speed and quality of an internet connection or network. It is calculated as the volume of data that can be transmitted from one point to another point within a network in a set period of time. Usually bandwidth is mentioned as bitrate and evaluated as bits per second (bps)

2. Literature survey

This section discusses about the survey conducted on scheduling, path computation and queuing techniques.

A. Queue Preference Scheduling

Multipath routing will not provide a desired quality of service for the multimedia data when the network has huge amount of traffic. So, an enhanced methodology like scheduling is essential. For eliminating frame losses when accomplishing QoS frame broadcasting, it plays a role of providing appropriate preference to each and every multimedia frames in relation to other data[5].

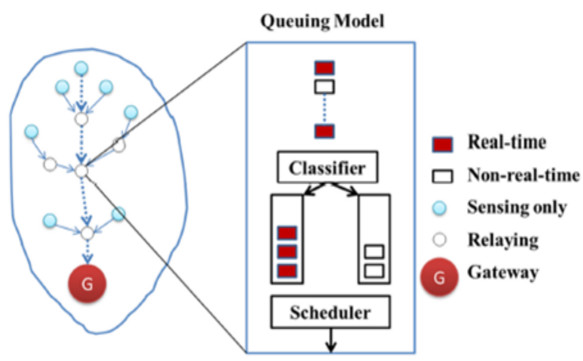

Figure 1: Queuing model

Message packets of sensors may begin from various preference sources with different traffic class variety. These are, real-time, loss-intolerant, delay tolerant, and loss-tolerant. The packet planning scheme of distinct traffic classes is taken in to account to represent the queuing design for a sensor as shown in Figure 1. A packet class and preference for each Cluster Head (CH) is assessed by a classifier and then forwards it to the relevant inside queues, structured and forwarded by a scheduler.

- According to the QoS necessities the diverse traffic produced from sensor nodes is separated as four classes.
- These are Delay Sensitive Traffic(DST),Reliability Sensitive Traffic (RST), Critical Traffic (CT),Best Effort Traffic (BET) . The priorities of these traffics are as follows,

PCT >PDST > PRST > PBET

B. Traffic Classification

Traffic categories [7] are segregated as follows;

Class 0: It consists of tight throughout hold up time limit that showcases delay-intolerant traffic, such as video traffic. Every video frame sends a continuous rate of frames and has a size of bytes.

Class 1:Image, acoustic, and PIR information are samples of this traffic that shows delay-tolerant traffic having flexible time limit throughout. Class1 traffic is designed as byte sized packets and transmitted at similar arrival rate as class 0.

Class 2: It has synchronization traffic or streaming and renovated route. Every packet is considered to arrive at the rate of packets/s have a size of bytes.

The highest preference is allocated to Class 0 traffic, Class 1 traffic is allocated with the second largest preference and the least preference is given to Class 2 traffic. Packets of every form of traffic are cushioned in discrete queues. Classes of queuing model are illustrated by Figure 2.

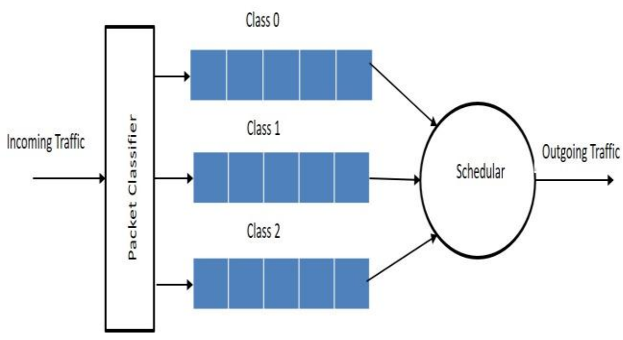

Figure 2: Different classes of Queuing model

A packet classifier which differentiates the arriving packets as per its preference and allocates it to relevant queue is destined for every node. Every queue consists of distinct back off model. If virtual collision occurs, Packets in greater preference queue are planned to move. As queuing design is used, providing numerous queues cannot enhance the memory overhead, distinct packet categories are split in unrelated queues rather than using single queue for storing. An injustice among diverse preference queues is caused by multi queue system. Packets in lower preference queues starve due to this. Explicit prioritization is applied in order to serve higher preference queue first by most of the protocols. Protocol continuously alters the preference of packets in lesser preference queues to offer some justice. After lapsing a set period of time in a lesser preference queue the

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preference of a packet is levelled up automatically, where it is transferred a level higher to a higher preference queue. The packets are organized within a queue as per the left-over time in time limit first, to further help the justice and QoS catering in the queuing scheme.

C. Control Functionality

Research focuses on identifying the characteristics of the packets based on the variety of application the packet adheres to. Two methods are used to find out packet preference such as, through use case deriving the packet or by previously defined area in the packet. For instance, the packet has high preference if the packets originate out of actual data resource. The packet has greater preference if the packet is scored as high preference in the area. The packet gets moved slower or faster as per the packet's preference.

Building up service standard pattern and service standard level based on traffic formation and data items marks the packet's preference at start node. Packet scoring algorithm is utilized to do this. Service Standard formation is differentiated in four types; Reliability, delay sensitive type, energy efficiency and rate of transmission. By looking through these categories the service standard level is separated in three levels; class 0, class 1 and class2(green, yellow and red) respectively. The service standard level is scored in preference field inside packet before transmitting it to sink node, once it is confirmed.

Concerned to types of stages, Class 0 shows the most important stage while Class 2 shows the lowest important stage. In addition, packet's preference level is stored in preference field of the packets. For classified service, Class 0 packet is assured to move first. Class 2 packets are considered the lowest significant so its damage is acknowledged as data could be regained at sink node by joining available packets. In between Class 0 and Class 2 the importance level of Class 1 is indicated.

In cases of specific application, the packets are differentiated into green, red and yellow packets to scatter the network traffic in separate paths in multipath algorithm. Shorter path is used by green packet for high standard transmission, while alternative path is taken by red packet. In the middle of green and red, yellow packet evaluates the path level of quality and distance.

D. Dynamic Preference Assignment

For real time applications data transmission requires reliable communication paths from source node to sink node. So it is mandatory to allocate the priorities to the packets dynamically. In network of wireless distinct classes of traffic, for applications, sensor nodes generate with distinct preference with application dedicated preference values. Consider SPji represent the source traffic importance of the traffic class j administering in the sensor node ni as shown in the formula,

$$DP_j^i = \frac{\delta_1 * N_{hops}^{i,\sin k} + SP_j^i}{\delta_2 * RD}$$

Where,

$N_{hops}^{i,\sin k}$

Source traffic preference of the traffic class j in sensor node ni

SP_j^i

Represents the number of hops from sensor node ni to sink node

RD is the deadline remaining time.

δ_1, δ_2 are the constants from 0 to 1.

E. Queuing Model of Traffic Aware Packet Scheduling Policy

Considering every node in a queue with an inter emerging and service time of the diverse traffic with non-deterministic then build model as an M/M/1.Node can have only one server. We can express the probability of mean hold time of the queue packets. Waiting time and time usage of the server is calculated as follows;

Rate of arrival of (T_a) and rate of service time (T_s).

To mean hold time in the queue (T_μ)

$T_\mu = 1/(T_s - T_a) - 1/T_s$

Total time usage of the server (T_u)

$T_u = (T_a) / T_s$

F. Packet Management of Queuing

As stated above, when there is large volume of traffic in the network, required quality in the perceived video alone cannot be attained using multipath routing. Hence, an additional methodology like scheduler is required. Such an additional mechanism plays a role of giving relevant preference for every frame in relation to distinct data for avoiding frame damages although accomplishing quality of service (QoS) in information streaming. Intermediate nodes need planning for methodology. This can enhance the data communication over WMSNs. Weighted Round Robin (RR) technique is used to perform classifications. Queues of intermediate nodes, buffer in queue preference scheduling. The free buffer size is taken in to account before allocating it in node's buffer for each packet reaching a node. The physical buffer length is cross verified with the sum of lengths of these four queues. If it is found equal, the packet is allocated to a queue as per its category. Allocating a packet in queues in order is as follows;

- First queue will be allocated with packet containing I-frame.
- Second queue will be allocated with packet containing P-frame.
- Third queue will be allocated with packet containing B-frame.
- Fourth queue will be allocated a packet without video data.

Scheduling pattern functions in this manner; the packets of three queues containing video packet having high priorities, are moved as intervening nodes cushion with round robin planning at first. Fourth queue sends one

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packet upon the network when these three queues do not have any packets, after this third queue is inspected for packet movement. If it contains packet for movement, it is moved and the round robin methodology is performed again in three queues consisting of video packet. The fourth queue transmits its packets if no video packet is present in a queue before it. It has weightage to say that the First-In-First-Out (FIFO) technique is utilized in every queue. The following are provided with the queue preference scheduling; maintaining equal importance for distinct video frames and video packets are prioritized over other packets. A video packet is transmitted quickly compared to other packets by doing this. This queue preference planning functions in the absence of knowing the nature of routing protocols [9]. Hence, usage of multiple routing protocols is efficient over path routing protocols in WMSNs. So, the queue preference scheduling is used rather than multi-path routing. The following Algorithms describe as follows: Algorithm 1 describes enquing packets in the nodes cushion, Algorithm 2 shows the queue planning mechanism for each node and score calculation of the path is shown in Algorithm 3 and algorithm 4 shows the Round Robin mechanism. So, the basic queuing management is as shown in Figure 3.

Packets having frames with type I-frame (Intra coded picture) are assigned the highest preference and then P-frame (Predictive coded picture) and B-frame (Bidirectional predictive coded picture), respectively as per the packet preference scheduling. Most trusted paths in the network are used to transmit packets with I-frames. The enqueuing and dequeuing mechanisms are to be considered for verifying the buffer size. The queuing policy [1] flowchart is shown in Figure 4.

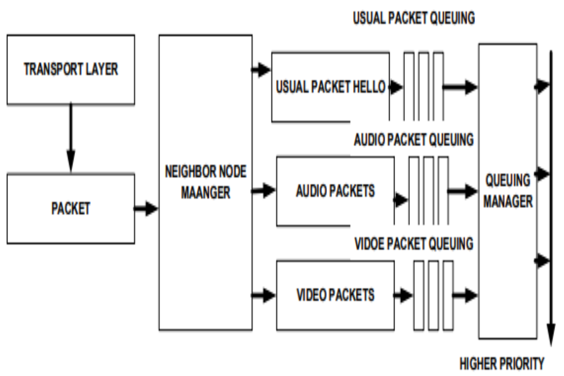

Figure 3: Basic Packet management of Queuing

Algorithm 1: Enqueuing [4] of receiving packets in everynode
for every node
if (total length of four queues) < (physical length of buffer)
Put the packets based on the type of packet in each queue;
Else Fall packet;

Algorithm 2: Queue scheduling [4]
for every node
X: for with video frames having any three queues execute RRS1;
if three buffers which have no packet
Then from fourth queue send one packet
Go to: X

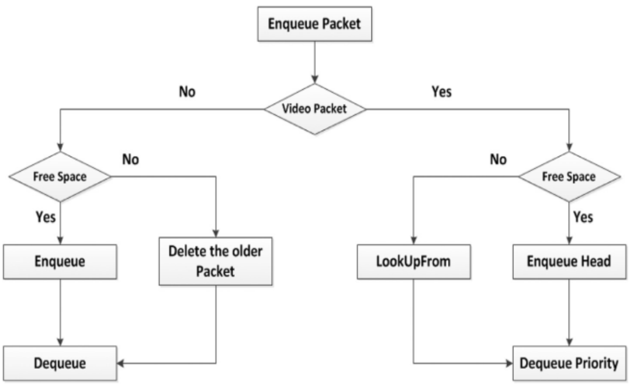

Figure 4: Queuing policy

G. Path Scheduling Computation

It is mandatory to know the condition of each path to identify highly reliable path. Data of every path is gathered using control packets. As per this information the path score is evaluated. The path with the highest score has best condition for transmitting the high priority packet.

Evaluation of every path score is as follows,

Path score = $\alpha W_L + \beta\, W_E + \gamma\, W_Q + \lambda\, W_H$

Where $\alpha + \beta + \gamma + \lambda = 1, 0 \leq \text{path score} \leq 1$

Depending on α, β, γ and λ coefficients the path score is calculated. Importance of its relatable component is affected by each coefficient. Depending on these considerations the coefficients are chosen.

W_E =Minimum residual energy in the path / E_0.

W_Q =Minimum Free buffer size in the path / B_0.

W_H = (1 + max hop count – hop count) /max hop count

WL = 1 –number of packets that do not satisfy requirement delay/number of received packets from each path.

The algorithm 3 represents the path score computation

Algorithm 3: Calculating Path Score and sorting path for every sink node
Compute path score
for video source node send path score
for every video source node
paths are arranged according to their sources
based on packet and queue scheduling send every video frame to one priority path

Algorithm 4: Round-Robin path selection for data transmission
Identify and Initialize the parameters
Arrange in ascending order based on path cost

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When an event occurs
while (!end of event)
if path count = 1
Single path routing
else Choose any one path from one to T by means of round robin technique then transmit data to target node

The following equation computes the path reliability

$$R_{e2e} = 1 - \left(R_{e2e} X\left(1 - R_{path}[i]\right)\right);$$
$$E_{e2e} = E_{e2e} + E_{path}[i];$$
$$D_{e2e} = D_{e2e} + D_{path}[i];$$

Where,
R_{e2e} - end-to-end reliability of the packets,
E_{e2e} -end-to-end energy consumption
D_{e2e} – end-to-end delay,
R_{path} – reliability, Epath – energy and D_{path} –data,
Paths with this the link performance among itself and its neighbor packets in terms of energy (E_{e2e}) reliability (R_{e2e}), distance to sink, delay (D_{e2e}) , and hop count. Metrics as per path are showed as (R_{path}); (E_{path}) and (D_{path}). The total end- to- end guarantee in multiple path routing on all the utilized paths is partitioned into end- to- end energy consumption (E_{e2e}),end-to-end reliability(R_{e2e})and end to end delay (D_{e2e}).

The WMSN is heterogeneous in its type, and is generated with video, audio, and temperature sensors. Jitter and packet delivery ratio are the metrics used to estimate the performance. The framework for multimedia transmission over WMSN is shown in Figure 5. It has four parts like packet Scheduling, video encoder, Queue Scheduling and Path Scheduling [10].

To evaluate multimedia communication problem such as wireless link failure, limited bandwidth, packet congestion and battery reserves, different cross layer communications among different layers are utilized by it. Application layer makes encodings according to channel status which communicates from physical layer, and then path scheduling is imposed to route the packets through distinct paths based on packet types [2].Finally, queue scheduling is imposed to release unimportant packets if there is network congestion.

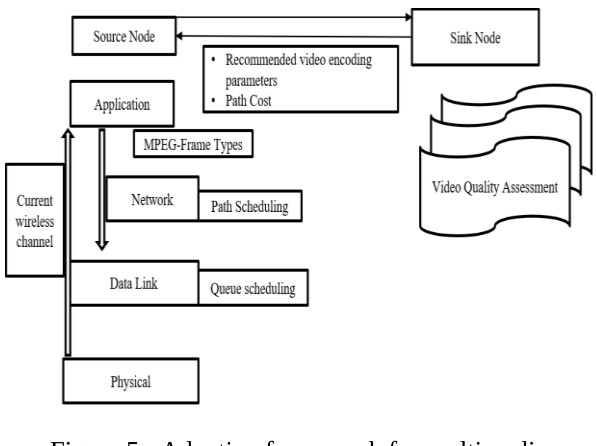

Figure 5: Adaptive framework for multimedia transmission over WMSN

H. Frame Operation

As coding and decoding of the two way interposed forecasting frames (B frames) may have to wait for the upcoming frames, only inter frames (I frames) and predicted frames (P frames) are utilized. A packet containing Inter frame information is called I frame packet, else it is a P frame packet. Separate kinds of frames have distinct and uncertain volume of Information. The I and P frame packets are created constantly and alternatively. The volume of data for P frame can be huge or tiny based on the movement of the objects, although I frame data is always larger. Even though few P frame packets get damaged the video decoding continues, as losing of packets in a wireless network is common feature, only causing few errors in the video. The consequence of the bygone packets is barely notable, if the bygone I frame packets are resent quickly. Hence, the fastest frame packets of the bygone I frame packets is necessary and I frame packets should have high preference compared to P frame packets. Figure 6 showcases the packet operations which are usually performed at a sensor node. When a data packet is created or received by a node, regardless of being an I frame packet or P frame packet it is initially allocated in the regular queue for waiting to be transmitted. After sending this packet, it is shifted to I frame packet pool or P frame packet pool based on its feature. Undecided packets are temporarily stored in these two pools, where they wait for retransmission if necessary. Say a single packet has huge volume of data that contains numerous frames, every packet should wait for all of the video frames created, and that results in additional time delay. The ever significant in assisting the actual playing is I frame. Hence, the resending of I frame packets has the highest preference in case it's lost. As it's possible to be discovered in the I frame packet pool, it can be inserted in lost I queue and retransmitted right after. Retransmission time and preference are the only contrast among the bygone I queue and the bygone P queue. Memory of the sensor node is utilized by I and P frame packets to stack the unknown packets, in the absence of affecting the regular sending and receiving of the sensor nodes. The [3] methodology differentiates the packets with distinct preferences and clarifies the coordinating and finding of the by gone packets.

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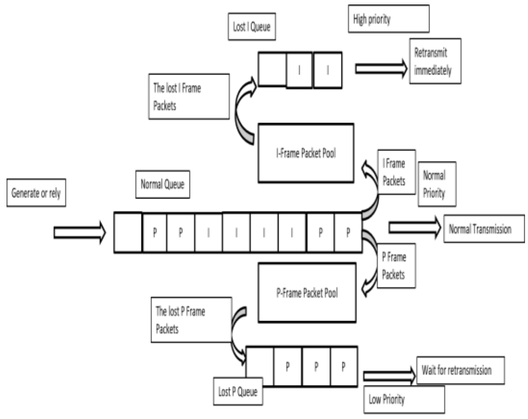

Figure 6: Frame operation

3. Proposed methodology

a) Enhanced equivalent capacity

An equivalent capacity is used to measure the bandwidth of an on-off traffic source. The enhanced identical capacity is utilized for calculating the productive bandwidth of overall traffic which is shown in Figure 7.For bit rate of every traffic, mean, second, third central moments, lag1 and autocorrelation is needed. With this numerical characteristic computing of numerical volume of the overall traffic takes place. Then, the 2-state Markov Modulated Poisson process (MMPP) approximates the overall traffic. The evaluated numerical traffic is used to gain the parameters of MMPP. The enhanced identical capacity formula is used to evaluate the identical capacity of the % state of MMPP.

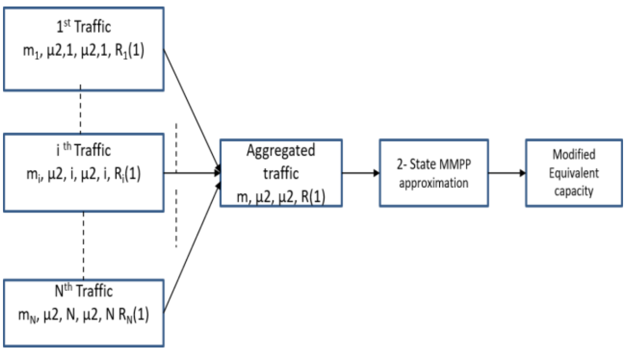

Figure 7: Enhanced equivalent capacity model

b) Gaussion Bound

Numerical bound of the bit rate of conglomerate traffic is termed as a Gaussion Bound. Productive bandwidth C is defined by, $C = m + \alpha\sigma$

Bit rate of combined traffic is represented by mean m and standard deviation σ respectively and α is given by,

$\alpha = \sqrt{2ln\left(\frac{1}{\epsilon}\right) - ln2\pi}$Here, probability of needed buffer overflow is given by e. Buffer overflow probability is said to be chances by which the buffer contents are more than the given buffer size.

c) Statistical characteristics of the aggregated traffic Computation.

Aggregated traffic numerical features provided by four parameters are as follows:

$$m = \sum_{i=1}^{N} m_i$$

$$\mu_2 = \sum_{i=1}^{N} \mu_{2,i}$$

$$\mu_3 = \sum_{i=1}^{N} \mu_{3,i}$$

$$R(1) = \sum_{i=1}^{N} \frac{\mu_{2,i}}{\mu_2} R_i(1)$$

Bit rate of the combined traffic are represented with mean m, second and third central moments μ_2, μ_3 and lag1 autocorrelation R(1), respectively. Similarly the bit rate of the i^{th} traffic source are represented by m_i, μ_2, μ_3,i, and R_i (1) which represents the mean, second, third central moments and lag1 autocorrelations. The amount of traffic sources are illustrated with N. Evaluation of the changed identical capacity is shown in Figure 8. In getting the introduced changed identical capacity, numerical features of the combined traffic are evaluated using those of individual traffics. Next, round off the combined traffic using a 2-state MMPP. At the end evaluate the productive bandwidth of the MMPP by changing the identical capacity formula.

d) Enhanced equivalent capacity

Aggregated traffic is combined and transformed into four parameters by a 2-state MMPP. A 2-state MMPP utilizes the association among the parameters of two constructs. The 2-state MMPP parameters are given by,

$$\tau_{high} = ln\left(\frac{1}{R(1)}\right)(1+\eta)$$

$$\tau_{low} = \frac{\eta ln\left(\frac{1}{R(1)}\right)}{(1+\eta)}$$

$$\lambda_{high} = m + \sqrt{\frac{\mu_2}{\eta}}$$

$$\lambda_{low} = m - \sqrt{\mu_2 \eta}$$

$where\ \eta = 1 + \frac{\delta}{2}\left(\delta - \sqrt{4+\delta^2}\right)\ and\ \delta = \frac{\mu_3}{\mu^{3/2}}, \tau_{high}\ and\ \tau_{low}$Formula represents the transition rates out of the high and low states. λ_{high} and λ_{low} represents the high and low states respectively for the subsequent arrival rates. The value between mean and peak bit rate is considered as an equivalent capacity. Enhance the equivalent capacity formula to estimate the equivalent capacity of MMPP, with the calculated 2state MMPP parameters.

Enhanced equivalent capacity C, is illustrated as follows,

$$C_m = (\lambda_{high} - \lambda_{low}) \frac{y - X + \sqrt{(y-X)^2 + 4X\rho y}}{2y} + \lambda_{low}$$

Buffer size is represented as X and the constants y and ρ are computed as,

$$y = ln\left(\frac{1}{\epsilon}\right)(1-\rho)(\lambda_{high} - \lambda_{low})/\tau_{high}$$

$$\rho = \tau_{low}/(\tau_{high} - \tau_{low})$$

An MMPP model is used as a biased on off model while deriving an enhanced equivalent capacity. Hence the proposed approach results in a stable estimate.

4. Conclusions

This research proposes the effective bandwidth mechanism to set the prime importance for scheduling and increasing the life time of the network for mission-critical sensor networks. The novel approach considers the models such as, packet scheduling model which is used for classifying different packet frames, an adaptive scheduling algorithm used for multimedia sensor nodes and finally, path scheduling model which discusses about the different path scheduling algorithms. Combination of all these models improves the performance. It also provides high average capture rate which influences the network lifetime. In the proposed approach the nodes partake in priority scheduling which shows an improvement in multimedia information delivery. It is clear that with path priority and the packets, to schedule high priority packets for transmission over high reliable path are the norm. Control packets are transmitted from source node across the routing path in order to gather information from every path. Over the time the network information may vary.

It is desired to develop this method further using NS2/ NS3 simulator for Wireless Multimedia Sensor Network data.

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