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Cross Layer Based Dynamic Traffic Scheduling Algorithm for Wireless Multimedia Sensor Network

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ABSTRACT- The data traffic volume is generally huge in multimedia networks since it comprises multimodal sensor nodes also communication takes place with variable capacity during video transmission. The data should be processed in a collision free mode. Therefore, the packets should be scheduled and prioritized dynamically. Dynamic traffic scheduling and optimal routing protocol with cross layer design is proposed here to select the energy efficient nodes and to transmit the scheduled data effectively. At first, the optimal routes are discovered by selecting the best prime nodes then the packets are dynamically scheduled on the basis of severity of data traffic. The proposed method works in two stages such as (*i*) Selection of chief nodes and (*ii*) Dynamic packet scheduling. The first stage of this mechanism is chief node selection and these chief nodes are selected for optimal routing. Selection of chief nodes is done by estimating the distance between the nodes, and energy value of the nodes. This stage makes the network energy efficient. The second stage is involved with dynamic scheduling of packets and sending the packets with respect to the Packet Priority of queue index key value. Real-time data packets (PQP1) have very high priority and it is scheduled using Earliest Deadline First Scheduling (EDFS) algorithm when compared to non-real time data packets (PQP2 and PQP3) which is scheduled on basis of First Come First Serve (FCFS) manner. This process minimizes the congestion and avoids the unnecessary transmission delay. Therefore, the results are analyzed through the simulation process and the efficiency of the proposed methodology is 56% better than the existing methodologies.

Keywords: Chief node selection; Packet Priority; Dynamic scheduling; Queue Index Key Value; Video Transmission.

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1. INTRODUCTION

There is a great demand for high quality and low latency real time video applications in the recent years. In recent years, the demand for low-latency and high-quality real-time video applications has been increasing rapidly. In these prospect multi-view video applications [1], virtual reality video applications [3] Ultra High-Definition videos [2] are being increasingly ubiquitous in multimedia-based applications. These multimedia-based applications require real time transmission of videos over wireless networks which exhibits wide difference in parameters like delay, coverage and throughput. In real time video transmission low latency, be the key metric for evaluating the performance of communication system. However, it is quite difficult to meet the requirements of ever-growing transmission of single wireless communication e.g., Wireless Local Area Networks (WLAN) can able to provide good throughput but it is limited to coverage area, High Speed Downlink Packet Access (HSDPA) and Long-Term Evolution (LTE) [4] which can able to offer coverage and mobility support but restricted with network throughput.

Integration of heterogeneous wireless networks (WLAN, LTE, HSDPA etc.) is considered to be an effective solution for transmitting the real time videos in those wireless networks concurrently. This process of transmission is referred to be as Concurrent Multipath Transmission (CMT) [5]. The CMT has the ability to transport the data in a parallel manner and also supports aggregation of bandwidth by utilizing the multiple network interfaces. In addition, CMT is considered to be a promising resolution key in heterogeneous network for both bandwidth aggregation and load balancing by using Stream Control Transmission Protocol (SCTP) in heterogeneous networks [6].

2. RELATED WORKS

Some of the protocols related to packet prioritization and packet scheduling algorithms are discussed. The Z-transform method [7] was introduced for modeling video bit-streams in terms of bit level distribution. Here CMT performance was also analyzed in terms of jitter, average transmission delay and outage probability of delay with respect to the probability statistics theory. Real time adaptive prediction model for video streaming over multiple wireless access networks was proposed in [8]. Here video bit streams with multiple links was designed using the principle theory of Markov decision process and dynamically splits into multiple routes. By using CMT relative model the Quality of Service (QoS) of video [9]. Nevertheless, bit level distribution of video packets does not involve with video sequences and specific video frames. Packet allocation is focused in most of the algorithms proposed earlier in order to improve the end-to-end delay constraints [10] for each video frames and video frame distortion.

Transport layer is the key research point for transmission control which has attracted considerable research attention. TCP-friendly SCTP based CMT solution [11] was applied with the purpose of achieving fairness in TCP flow and load sharing. An innovative window-based mechanism [12] was proposed for flow control to balance delivery fairness and efficiency on the basis of the data-link layer and rate/BW estimation at the transport layer.

Transmission rate control algorithms are most particularly modeled for low latency real time video transmission. An algorithm named delay constrained rate control model [13] was proposed to achieve an efficient utilization low latency along with distributed sharing bandwidth and fairness of distortion. The packet flow gets adjusted dynamically with respect to its traffic load and according to the traffic load the scheduling policies are designed in the scheme of joint rate control algorithm [14].

A scheme based on real time CMT of video in heterogeneous access network was proposed to derive the efficient video transmission. Here the model was derived named Multipath Buffer Analysis Model (MBAM) [15] for achieving the targeted video frame bits by deriving the upper and lower bounds of video bits. However, the packet rate control problem was not considered in MBAM analysis. Therefore, by taking the quality of received video and low-latency a Buffer-driven Rate Control and Packet Distribution (BRCPD) algorithm [16] was proposed in order to achieve the fairness rate control and buffer awareness of multipath transmission on basis of MBAM.

3. DYNAMIC TRAFFIC SCHEDULING AND OPTIMAL ROUTING

Dynamic Traffic Scheduling and Optimal Routing (DTSOR) protocol is proposed along with the application of cross layer design. Proposed methodology DTSOR has two significant stages such as *(i)* selection of chief nodes and *(ii)* transmitting congestion free data traffic. The first stage of this mechanism is selection of chief nodes and these chief nodes are selected for optimal routing. Selection of chief nodes is done by estimating the distance between the nodes, energy value and bandwidth availability of the nodes. The second stage is scheduling the packets and sending in priority queues that reduces the congestion and avoids the unnecessary transmission delay.

3.1 Process of Chief Node Selection

The chief nodes are selected as router nodes from the source to destination. The chief nodes are selected by estimating the energy residing value, distance between the nodes and the nodes that are closest towards the base station.

3.1.1 Residing Energy Estimation

The nodes are deployed with full battery power initially and later on the energy level of the nodes get decreased gradually with respect to their usage level. The node's energy spending process includes ON, OFF, SENSE, D_T, D_R and SWITCH. The node spent energy for each and every process that performs. For ON and OFF process some amount of energy is spent similarly certain amount of energy will be spent for data transmission and data receiving process with respect to their transmission load. Also, certain amount of energy will be spent for sensing the data and some energy level gets consumed for node switching process. Also, energy is consumed for retransmission purpose if there any data loss occurs. Consequently, the energy consumed by the node for the set of data transmission process includes all the process such as E_{ON}, E_{SENSE}, $E_{TRANSMIT}$, $E_{RECEIVE}$, E_{OFF} can be calculated. *Equation 1* gives the computation of total energy 'E_{COM}' by the node for a set of data transmission,

$$E_{CON} = E_{ON} + E_{SENSE} + E_{TRANSMIT} + E_{RECEIVE} + E_{OFF} \quad (1)$$

The node energy level is determined each and every set of data transmission in order to select the high energy nodes for the data transmission process. The same node cannot be selected for more number of transmissions since the energy level might get decreased. Therefore, it is necessary to calculate the consumption of energy 'E_{CON}' after each set of transmission. The total energy level used 'E_T' for each set of transmission is calculated using *equation 2.*

$$E_T = 1 - E_{CON} \quad (2)$$

The residual or remaining energy '$E_{RESIDUE}$' in each node is identified by taking the difference between the initial power presented during the node deployment and the total energy consumed during the previous transmissions. Initial allotted energy level is represented to be 'E_{INI}' and the residue energy level estimation is done using *equation 3*.

$$E_{RESIDUE} = E_{INI} - E_T \quad (3)$$

Once the energy efficient nodes are determined then distance between the routing nodes are determined in order to select the chief nodes for data transmission.

3.1.2 Distance Estimation

Distance between the nodes is calculated for effective communication since the strongest link between the nodes is necessary for congestion free data transmission. The link estimation is done to identify the communication range for each and every currently acting source node and its neighbour node until it reaches the destination. By taking the node vertices of current source node and its neighbour node (x_m, y_n) and (x_n, y_m) respectively. Hence the distance (Dt) can be formulated using *equation 4.*

$$Dt_{(m,n)} = \sqrt{(X_m - Y_n)^2 - (X_m - Y_n)^2} \quad (4)$$

The distance between each and every nodes is calculated and the minimum distant nodes are taken for the data transmission. The minimum distant nodes are selected by using the *equation 5*.

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$$D(s) = Min(d_i, d_j) \forall N_i \quad (5)$$

The minimum distant nodes are selected by computing average distance between the nodes. The average distance between each and every nodes towards the gateway is calculated using *equation 6*.

$$Avg\ D(n_{i,j}) = \frac{min(d_i, d_j)}{T} \forall Ni \quad (6)$$

By collecting the minimum distant and energy efficient nodes the chief nodes are elected for data transmission. The sensed data is transmitted on the basis of traffic priority and therefore the packet queues are scheduled using dynamic priority scheduler.

3.2 Process of Dynamic Priority Scheduling

By considering the data traffickers severity the data packets are scheduled and it comes under the categories followed by Packet Queue Priority 1 (PQP1), Packet Queue Priority 2 (PQP2) and Packet Queue Priority 3 (PQP3). The packets are scheduled on the basis of Earliest Deadline First Scheduling (EDFS) algorithm. The system allocates the resource information and process of synchronization on basis of priorities of packet queues. Based on real time application the queue table is used to prioritize the data packets.

In general node consists of two or more queues and based on the priorities and types the packets are kept inside the queues. The ready queue gets separated into three levels of priorities. A real-time data packet with highest priority is kept in first priority queue and it is processed using First Come First Served basis. Non-real time data packets are queued into the lower PQP2 and PQP3 priority levels and processed packet scheduling algorithm. Data packets are scheduled in each queue or among different queues. A node at the lowest level has lesser number of queues whereas a node at the higher level has many queues in order to minimize the average transmission delay from source to destination and maintains low energy consumption throughout the network.

3.2.1 Packet Queue Priority 1 (PQP1)

The packet queue holds the earlier deadline value have higher prioritized packet queue. This high priority class is indexed for supporting the critical real time applications in emergency conditions. High priority holds earlier deadline since the packets should deliver to the gateway within their periodic value (for exemplar (Hp → 0<Hp<35) *i.e.* the high priority key value index falls between 0 to 35) so that the critical rescue operations in healthcare monitoring of patients observations include abnormal heart rhythm, arterial fibrillation, low blood potassium, military and aircraft applications etc. For such kind of applications highest priority packet queue (time slot) is allotted. Since PQP1 is acyclic in nature and therefore it always handles high prioritized packet queues.

3.2.2 Packet Queue Priority 2 (PQP2)

Secondly prioritized packet queues holds the key value index between 36 and 75 i.e. Ap → 36<Ap<75. Here the packet queues are prioritized in average manner so that PQP2 can able to handle both the extremely critical conditions as well as serious environmental circumstances. Therefore, the data packets can be sent through either cyclic periodic time or acyclic periodic time of traffic with high repetition rate.

3.2.3 Packet Queue Priority 3 (PQP3)

Low prioritized packets hold the key value index between 76 and 99 (76<Lp<99) and this type of low priority queues are allotted to periodic transmission. The sensed data are not time stamped and the time slots can be adjusted in some extent for high prioritized packet queues. Low prioritized packet queues are dynamically applied for non-critical applications.

Table 1: Classification of Packet Queue

Queue type	Packet Priority	Data traffic type
High	PQP1	Critical
Average	PQP2	Critical & Non-Critical
Low	PQP3	Non-Critical

Table 1 shows the level of priority wise of packets with respect to various traffic conditions and also the conditions with latency tolerance. The packet frames which are received from the sensor is given as scheduling input that contains the data and Packet Priority (PP). Based on PP key index value, the priority of the packet is verified. If the packet has low earlier key value index and it is added in the series of Hp and forwarded to the scheduler. If the node has high earlier key value index, then it is added into Lp and the packets are transmitted to the scheduler. Correspondingly, the median key value index is given to the average priority packets and finally forwarded to the scheduler.

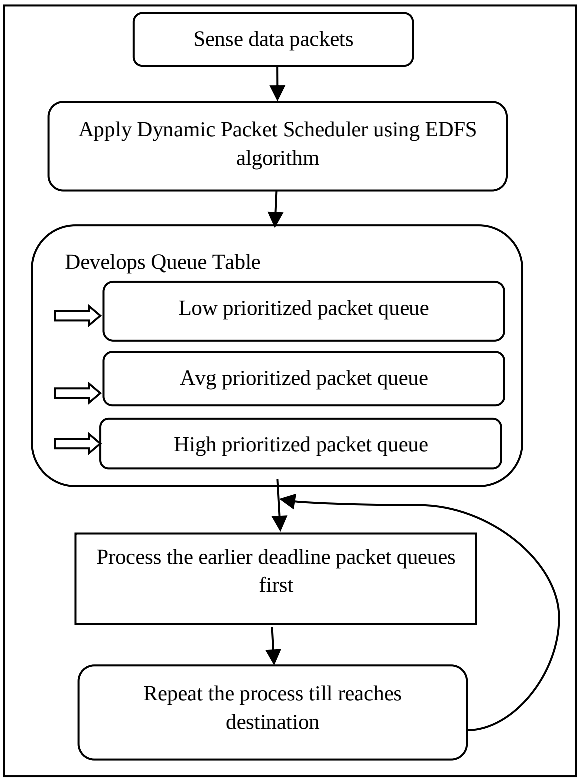

Figure 1: Dynamic Scheduling using EDFS Algorithm

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4. RESULTS AND DISCUSSION

The experiments are carried out using the simulator tool called Network Simulator (NS) of version 2.35. The proposed DTSOR scheme and the comparative conventional protocols such as MBAM and BRCPD schemes. The simulation parameters taken into consideration are defined in the *table 2*. By taking link connectivity or distance among nodes, their energy level and the amount of data traffic can be sent over the channel are the metrics taken here to identify the active intermediate reliable nodes by using cross-layer approach interaction among all the layers. This model results in identifying the reliable and efficient route for data forwarding process with low congestion and less delay.

Table 2: Simulation Parameters

Parameter	Value
Channel Category	Wireless Channel
System Interface Type	WirelessPhy
Node Count	100
Time for Simulation	100 sec
Type of MAC	802.11
Traffic Model	CBR
Communication Range	250m
Data Rate	11Mbps

The metrics taken for the analysis of MBAM, BRCPD and DTSOR protocols are packet delivery rate, Energy consumption of nodes, Average transmission delay, Average wait time and Scheduling overheads.

4.1 Packet Delivery Rate

Packet Delivery Rate (PDR) is defined as the amount of packets that can be delivered successfully to the sink node with respect to the total amount of packets sent by base node. PDR is measured using *equation 7*.

$$PDR = \frac{\sum_0^n No.of\ Pkts\ Received}{Time} \quad (7)$$

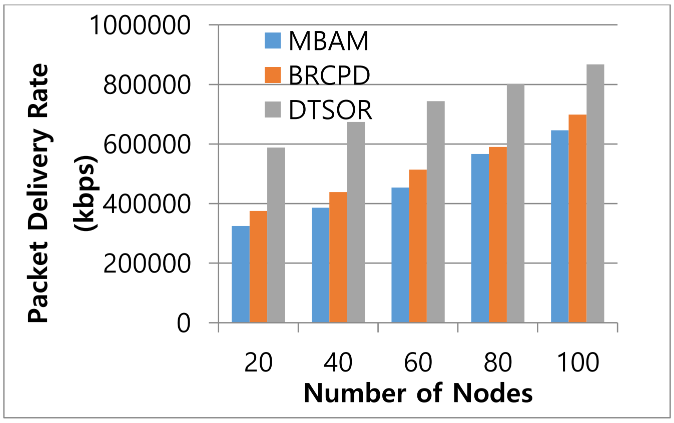

Figure 2: Packet Delivery Rate

Figure 2 shows graphical representation of PDR for both the proposed DTSOR scheme and conventional methods such as MBAM and BRCPD are simulated using NS2.35. It is clearly shown that the DTSOR scheme has better data packet (video frames) delivery rates at receiver side compared to conventional methods.

4.2 Scheduling Overheads

Path scheduling and packet scheduling process greatly reduces the data overheads (congestion) also decreases unnecessary delays in receiving the packets of cost metrics. *Figure 3* shows the graphical representation of scheduling overheads for both proposed method DTSOR and conventional schemes MBAM and BRCPD. It reduces the path scheduling cost in regards to the number of participates nodes while routing. The obtained scheduling overhead results of MBAM, BRCPD and DTSOR are analysed and verified that DTSOR is better compared to conventional protocols.

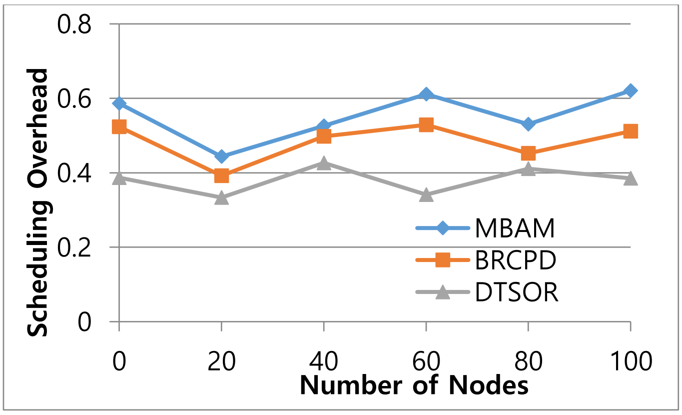

Figure 3: Scheduling Overheads

4.3 Energy Consumption

Relative energy level for each and every node should be calculated in the network that also used for data transmission process.

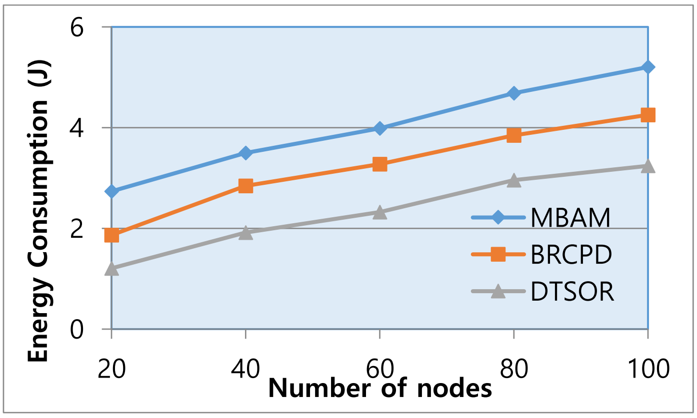

Figure 4: Energy Consumption

Nodes Energy Consumption Value (E_{CR}) that is used for transferring the frames and to maintain the node in active role is calculated using nodes energy drain rate. *Figure 4* shows the consumption of energy values for each process that involves in data transmission procedure. Energy computation is measured in terms of joules for both the proposed DTSOR method and conventional schemes. DTSOR method utilizes less value of energy resource since it selects the optimal or chief relay nodes for routing or transferring the packets or frames of video sequences.

4.4 Average Transmission Delay

Average packet transmission is measured to calculate the transmission time that is taken for a set of data transmission process from source node to sink node. It is defined as the time difference between the packets received by the receiver node and the packets sent by the base node. Average transmission delay is measured using *equation 8*.

$$\text{Transmission Delay} = \frac{\sum_{0}^{n} Pkt\ RCVD\ Time - Pkt\ Sent\ Time}{n} \quad (8)$$

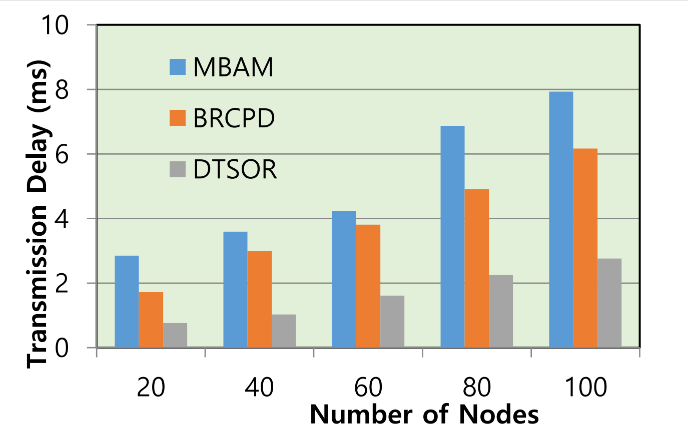

Figure 5: Average Transmission Delay

Figure 5 shows graphical representation of transmission delay of packets for the conventional schemes MBAM and BRCPD and proposed DTSOR method. The packet or data transmission delay is reduced by scheduling the packets on priority wise in DTSOR method and thereby reduces congestion in the data channel. Hence the obtained delay value is low compared to the conventional schemes of MBAM and BRCPD.

4.5 Average Waiting Time

Based on the priority and packet types, packets at the nodes must be scheduled. Real-time data packets are considered as the highest priority packets and it is processed first to the base station since it possess the earliest deadline.

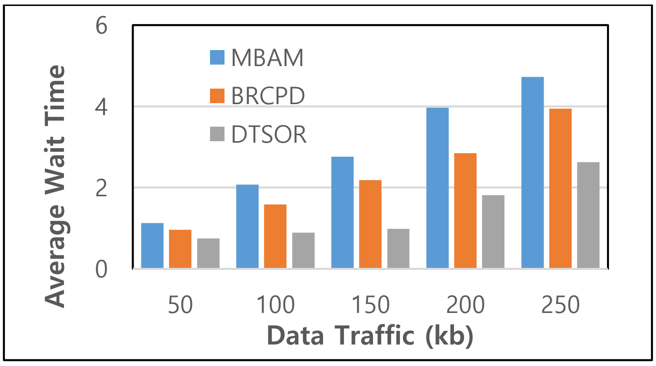

Figure 6: Average Waiting Time Vs Data Traffic

Low prioritized packets are non-real time packets and it has no any critical time delay in delivering the packets to base station. *Figure 6* represents the average waiting time for the protocols DTSOR and conventional schemes MBAM and BRCPD. The average waiting time for the proposed scheme DTSOR is low compared to MBAM and BRCPD methods. High priority packets are processed first and hence it has low average waiting time but the queue length of packets may be variable.

5. CONCLUSION

DTSOR protocol along with cross layer design is proposed to schedule the data packets effectively to avoid congestions. This scheme segmented into two stages such as selection of chief nodes and transmitting congestion free data traffic. Selection of chief nodes is done by estimating the distance and energy values of the nodes. Chief nodes are elected for optimal routing and makes the network energy efficient. Second level includes dynamic packet scheduling and sending the packets in priority queues reduces congestion, transmission delay, waiting time and also avoids unnecessary energy consumption throughout the network. Simulation analysis is carried out to prove the efficiency of the DTSOR scheme which is 56% better in terms of delivery rates compared to conventional schemes.

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