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An Enhanced Scheduling Technique To Maintain Qos In Real Time Data Communication In Wireless Mesh Networking

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Abstract: Wireless mesh networks (WMNs) are a promising technology development aiding seamless communication and interference less communication across heterogeneous environment. Due to the presence of heterogeneous devices, the rate of traffic flow is least organized with the devices resulting in performance degradation. In this article, distributed traffic scheduling (DTS) with dynamic queue management (QM) is discussed. The aim of this proposed method is to improve the quality of service (QoS) of WMN users. This method addresses traffic scheduling and queue management as a linear optimal problem to maximize network throughput. QoS optimization is achieved by suppressing the constraints in a representation plane for resolving transmission and queuing errors while handling multiple flows. This method is effective for resource constraint scalable WMN users demanding a better QoS. The dynamic queue management process permits effective acquisition and allocation of flows of varying packet sizes. The performance of the proposed method is verified using simulation and the metricssuch as throughput, delay, packet loss and slots are assessed.

Keywords: QoS, Queue Management, Scheduling, Traffic Allocation, Wireless Mesh Networks.

1. INTRODUCTION

Wireless mesh networks (WMNs) has emerged as a prominent technology in the recent years for commercial, industrial, and residential applications. WMN encompasses different communication technologies and distributed networks for providing seamless access and control over the resources. The aim of WMNs is to provide cost-effective and tardiness-less communication solution for the connected users belonging to different regions. Mesh network encompasses mesh routers (WMR) and internet

gateways (GW) for facilitating to-and-fro communication [1].The communication seamlessness and interoperable features with the other platforms and networks is aided by these devices in the network. WMR is capable of relaying and transmitting data packets in intra and inter connected networks. GW acts as access point for sending and receiving packets across the different platforms [2]. GW is capable of connecting the networks with other distributed resources such as cloud.

The devices are classified depending upon their functions; a backhauling device is capable of relaying packets between GWs. With the help of distributed resources and communication platform, WMN scalesa wide-perspective. The radio-enabled communication technologies interconnect different density of networks reducing the redundancy and replication errors. Communication is aided through single or multi-hop depending on the distance of separation of the devices in the network. The devices adapt different protocol and wireless standards to improve their self-organizing and topology-bound characteristics [3]. The organization of WMR and users rely on multiple factors such as delay, bandwidth, resource allocation, etc. These factors are required to improve the traffic handling rate irrespective of the varying user density and application flow rates. In order to meet the quality of service (QoS) requirements with less packet transmission error rate, the network inherits the advantages of the connected heterogeneous platform [4]. Communication effectiveness is fundamental requirement for improving the QoS of the network by augmenting the capacity of the users by altering the physical and virtual behavior attributes of the devices. Antenna utilization, queuing and scheduling, admission control, range variation, channel utilization, radio control are some of the attributes that are calibrated in the communication environment for improving the service quality in WMNs [5]. To improve the rate of QoS in WMNs, the different protocols, cross layer designs, and media access control based techniques are incorporated for the network. The aim of these methods is to improve the channel utilization rate along with the capacity of the communicating users/ nodes. QoS optimizations focus in reducing latency and ensure better network throughput despite of the varying packet size and traffic density. In particular, the nodes experience heterogeneous traffic across different communication links, handling different user requests at the same communication interval/ slot. With the interoperable and heterogeneous operations of the devices and the network communication nature, the QoS demands of the users are satisfied in an optimal manner [5, 6].

The efficiency of WMN devices relies on the spectral utilization rate observed in a particular communication interval/ slot. Robustness in service and QoS satisfaction are decided by the rate of spectrum utilization and the channel utilization capacity of the centralized or decentralized devices. Scheduling resources and traffic across the available links is one of the prominent ways to organize WMN communications [7]. Fair scheduling and link organization improves the rate of resource allocation and sharing across multiple communicating terminals. Scheduling is either centralized or distributed depending on the type of user and controllers present in the network. More specifically, in order to avoid congested transmissions and overloaded links, traffic scheduling is likely to be recommended for the autonomous device operations. Scheduling traffic across multiple links improves the flow rate with less transmission errors. Besides, the fundamental requirements such as throughput maximization and latency-less transmissions are feasible through constraint analyzed scheduling. The scheduling constraints such as delay and bandwidth are prominently considered along with the physical attributes of the nodes [8, 9].

2. RELATED WORKS

Favraud et al. [10] presented a radio access network infrastructure for improving the QoS of long term evolution (LTE) formed using autonomous users. The authors introduced optimal resource scheduling in this architecture for improving the QoS by improving the flexibility of transmission. The transmission reliability is improved by analyzing real-time traffic for user demands.

Markov model based routing is designed for wireless mesh networks by Zhang et al. [11] for improving the resource allocation and utilization rate of the users. This routing is designed in an opportunistic manner for handling batch jobs for independent users. This routing relies on pipelined transmissions and mapping packet transmission for improving the performance of multi-hop wireless mesh networks.

Nawaz et al. [12]introduced a physical layer scheduling approach for organizing data flows in co-operative on-demand networks. This approach identifies the communication schedule of all the users on the basis of their duty-cycle process. The consecutive transmissions of the users are modeled with respect to time using Markov model. An advantage of this method is its assimilation of sub-carriers of different signal strength.

A batch processing dependent scheduling and inventory managementis introduced for wireless mesh network by Liao et al. [13]. This scheduling process is intended to improve capacity maximization and cost efficiency of the batch processing network. This scheduling and inventory management method is reliable in improving the delivery rate of the users irrespective of the varying flows and packet density.

Chen et al. [14] designed a mixed integer linear programming (MILP) based scheduling optimization for multi-product pipeline network. This programming model accounts the flow and arrival rate, batch density, transmission slots for organizing the incoming batches across the different user pipelines. This scheduling achieves better inventory management.

Regional condition-aware hybrid routing protocol (RCA-HRP) is projected by Chai and Zeng [15] for improving the performance of wireless mesh network. This routing protocol assimilates the advantages of both reactive and proactive routing for scheduling transmission on the basis of regions. The traffic load offered by the mesh devices are accounted for scheduling across neighbor discovered regions. This routing protocol improves network throughput and reduces latency and packet drops. Min et al. [16] introduced joint resource scheduling (JRS) for improving the scalable (S) and manageable (M) nature of wireless mesh networks. This scheduling method relies on cloud resource and optimization for improving the throughput of the network by allocating optimal schedules for transmission. Data scheduling is based on adaptive data control designed using cross-layer design. This method focusses on reducing the interference of the network and improving the data rate with respect to the communicating paths.

Minimum cost routing (MinCosRO) introduced by Li et al. [17] is intended to improve the network throughput of software-defined wireless networks. This routing is more specific for full-duplex networks where congestion and interference are high. Neighbor selection and link organized transmissions are the considerations in this routing algorithm for addressing NP hard problem in a heuristic manner.

Farzinvash [18]discussed a multicast tree based QoS optimization for multi-radio mesh networks. This optimization method accounts the delay and channel constraints at the time of transmission to mitigate the impacts of overlapped channels and neighbors. This multicast optimization is designed for the networks handling multimedia services in which a high flow acceptance rate is achieved.

Shang et al. [19]designed an admission control algorithm for improving the performance of service concentric wireless mesh networks. The admission control and scheduling process are designed using matching game process and decision-making. The decision-making is preceded using multiple features of the network and nodes indulged in transmission process.

This admission control and scheduling process balances user requirements and resource availability.
To address the issues in QoS multicast optimization, Meraihi et al. [20] proposed a modified bat based optimization. The multicast routing optimization relies on delay, bandwidth and packet loss factors for selecting optimal transmission routes. The conventional bat algorithm is modified by introducing inertial weight.

The map based analyzed Gaussian distribution with the velocity update helps to achieve optimal solutions.Stable and reliable in multi-path QoS multicast routing protocol (SR-MQMR) is designed by Vaighan and Jamali [21] for improving the performance of mobile ad-hoc networks. This routing protocol identifies link stability enduring neighbors for transmitting packets across the network. Bandwidth and signal strength of the nodes determines its participation in the communication path. This routing protocol achieves better success ratio and less overhead.

Shafigh et al. [22]proposed a fuzzy logic based multicast routing scheme for improving the QoS of ad-hoc networks. This routing scheme is dynamic in resource handling and allocation irrespective of the incoming network traffic. The transmission is scheduled on the factors of delay and delivery ratio by the independent sources. This helps to maximize the QoS of the independent users in the network.

3. PROPOSED METHODOLOGY

Distributed Traffic scheduling and Queue Management (DTS-QM) Method

The proposed DTS-QM, as the name suggests performs traffic scheduling and queue management independently in a wireless mesh network. Scheduling is fortified with the nature of the nodes in handling data packets and thereby allocating queues for stagnant-free transmissions. The harmonized aim this method is to leverage the QoS of WMN network supportive applications.Though the different functions relay on distinct note attributes, the process is harmonized using linear optimization for mitigating congestion and improving QoS of the network. The following section provides the network model and methodology of the proposed DTS-QM. Figure1 illustrates conventional WMN.

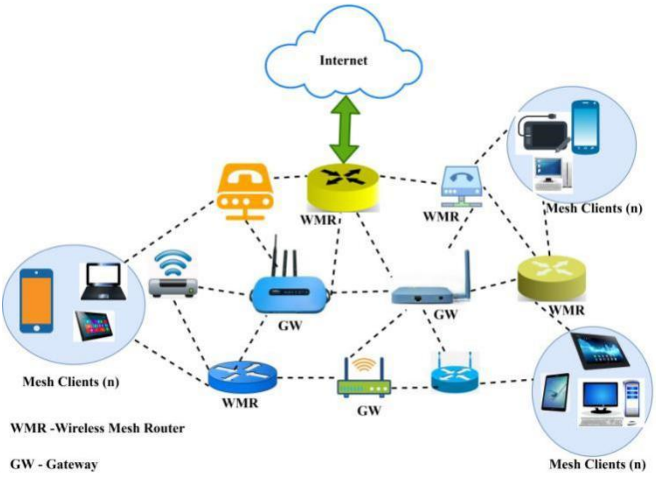


Figure 1 Conventional WMN Illustration

Network Model

The proposed method is considered to have n mesh nodes that are interconnected through hyper arcs $'a'$. Therefore, the network is represented as ahyper plane H with (n, a) graph connected nodes. The nodes possess two-way communication and those neighbors that are away from the communication range (R) are reached in multi-hops. The arcs are nothing but wireless bi-directional links. Each node is capable of generating packet flows augmenting to the network traffic. Let p_s represent the flow from each of the connected node. The nodes follow a concave function for maximizing p_s. The rate of increase in p_s increase the number of packets transmitted and the delivery ratio of the network. If f_c is the concave function, then the objective is framed as

$$\left.\begin{array}{c} argmax\ \sum_{p_s} f_c(p_s \times t_t) \\ such\ that \\ \sum_a \max_{p_s} \left\{ p_s \times t_t \times \frac{1}{\rho_i} . \alpha_t \right\} \ \forall\ n \in R \\ and \\ \sum_a \alpha_t = 1\ \forall\ a \in n\ in\ R \end{array}\right\} \quad (1)$$

Where t_t is the transmission time, ρ_i is the idle probability of the node, α_t is the transmission factor. The transmission factor is always high for a node in the range that is connected through a bi-directional arc (link). The "such that" constraints in equation (1) needs to be satisfied for all the transmissions between source and destination that ensures optimal traffic distribution.

The traffic distribution in a WMN requires scheduling transmission links and dynamic queue management. This means, for any $(p_s \times t_t)$ the available link must maximize f_c by decreasing the packet drop probability(ρ_d). This distribution of traffic requires a slotted scheduling with respect to t_t irrespective of f_c. There are three factors influencing the scheduling process namely α_t, transmission probability p_t and network throughput $\sum p_s/t_r)$, where t_r is the traffic receiving time. These three factors are connected in order to achieve sustained traffic scheduling across each of the links in the communication environment. The linear optimization model proceeds over each factor independently top schedule traffic on the basis of available opportunistic feature/factor of a node. If a node satisfied any of the above factors for maximizing f_c, then the incoming traffic is scheduled. In equation (2), the estimation of α_t and ρ_t is presented

$$\left.\begin{array}{c} \alpha_t = \frac{p_s}{p_t} \\ \rho_t = \sum_{i=1}^{n} \frac{n_{t_i}}{1-n_{t_i}} \prod_{i=1}^{n} \left(1 - n_{t_i}\right), \forall\ n \in R \\ such\ that \\ \rho_b = 1 - \prod_{i=1}^{n} \left(1 - n_{t_i}\right) and \\ \rho_i = 1 - \rho_b \\ provided\ \rho_b > \rho_i \end{array}\right\} (2)$$

Where p_t is the incoming flow arrival rate for transmission, n_t is the currently transmitting node count, ρ_b is the busy node probability and ρ_i is the idle probability of a node. The transmission factor is dependent on ρ_b and ρ_i of a node and hence it is mandatory in both $\rho_t$and $\sum \frac{p_s}{t_s}$ principal optimization. The following section provides linear square optimization induced for addressing the traffic scheduling across (n, a) for satisfying equation (1)

Scheduling based on α_t

The transmission factor determines the rate of flow between the nodes connected by a.
The objective of equation (1) (i.e.)$argmax \sum_{p_s} f_c(p_s \times t_t)$ is balanced with $\max\{\alpha_t\}$ for all the arcs till the destination. The function f_c is framed as per the transmission factor, if α_t is high, loss is less and vice versa. Therefore selecting optimal n between the source and destination is mandatory. Instead, the neighbors are also not selected by completely relaying onα_t. The possible changes in neighbors p_s is subject to change with ρ_i and ρ_b of its successive/multi-hop neighbor. Therefore, the normalization the function$f_c = \sum_{p_s}(p_s \times t_t) \,.\, \alpha_t + e$, where e is the error in α_t(i.e.) the node selected for transmitting the flows results in loss. The linear optimization considers two planes in a 3-dimmemsional space (i.e.) packet loss and p_s where $f_c = (p_s \times t_t). \alpha_t + e$ is expressed as a plane as in Figure 2(a) and 2(b) with different conditions.

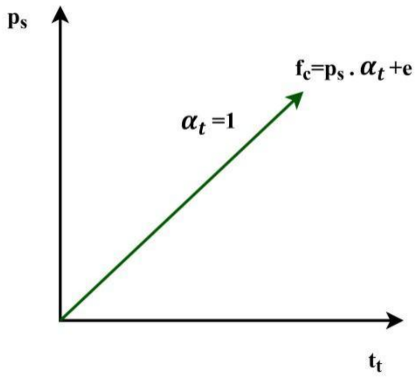


Figure 2(a)$\alpha_t = 1, e = 0$ Condition

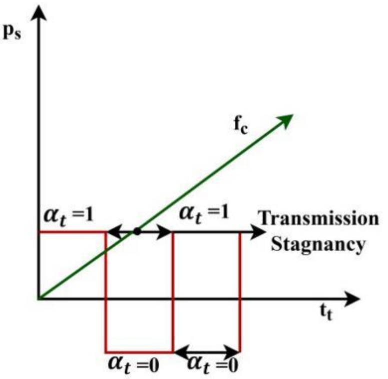


Figure 2(b)$\alpha_t = 0, e \neq 0$ Condition

The solution for two different conditions $(\alpha_t = 1, e = 0)$ and $(\alpha_t = 0, e \neq 0)$ is presented in the above Figure. This representation is analyzed for $t_t = 1$ to y transmissions that is expressed as

$$\left.\begin{array}{c} f_{c1} = p_{r1} \\ f_{c2} = p_{r1} + p_{r2} \\ \vdots \\ f_{cn} = p_{r1} + p_{r2} + \cdots p_{rn} \\ LHS \end{array}\right| \begin{array}{c} f_{c1} = p_{s1} . \alpha_t + \left(1 + \frac{p_{r1}}{p_{s1}}\right) \\ f_{c2} = p_{s1} + p_{s2} . \alpha_t + \left(1 + \frac{p_{r2}}{p_{s2}}\right) \\ \vdots \\ f_{cn} = p_{s1} + p_{s2} + \cdots + p_{sn} . \alpha_t + \left(1 + \frac{p_{rn}}{p_{sn}}\right) \\ RHS \end{array} \quad (3)$$

The above equations are represented for the independent space representations of α_t and $e$for p_s. The LHS of the above equation denotes the variation of f_c for all$\alpha_t = 1$ and the RHS represents the variation for e=1. The transmission factor and e are inversely proportional and the same is expedited in all the transmission from 1 to y. The final error is estimated using equation (4) as

$$e = \sum_{i=1}^{y}\left[f_{ci} - \sum_{j=1}^{p_s} \alpha_t.\,(p_{ti} - p_{si})\right] \tag{4}$$

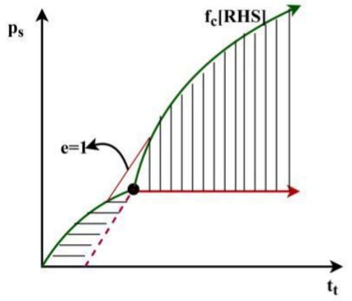
From equation (3) and (4), the objective as in equation (1) is verified using a matrix representation such that both the LHS and RHS of the equation (3) is correlated with $(p_s \times t_t)$. The matrix (linear) form of the LHS of equation (4) and error in equation (4) is estimated as

$$\begin{bmatrix} p_{s11}\,t_{t11} & p_{s12}\,t_{t12} & \cdots & p_{s1y}\,t_{t1n} \\ p_{s21}\,t_{t21} & p_{s22}\,t_{t22} & \cdots & p_{s2y}\,t_{t2y} \\ \vdots & \vdots & \vdots & \vdots \\ p_{sa1}\,t_{ta1} & p_{sa2}\,t_{ta2} & \cdots & p_{say}\,t_{tay} \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_n \end{bmatrix} = \alpha_t \begin{bmatrix} \frac{p_{r11}}{t_{r11}} & \frac{p_{r12}}{t_{r12}} & \cdots & \frac{p_{r1y}}{t_{r1y}} \\ \frac{p_{r21}}{t_{r21}} & \frac{p_{r22}}{t_{r22}} & \cdots & \frac{p_{r2y}}{t_{r2y}} \\ \vdots & \vdots & \cdots & \vdots \\ \frac{p_{rn1}}{t_{rn1}} & \frac{p_{ra2}}{t_{ra2}} & \cdots & \frac{p_{ray}}{t_{ray}} \end{bmatrix} \tag{5}$$

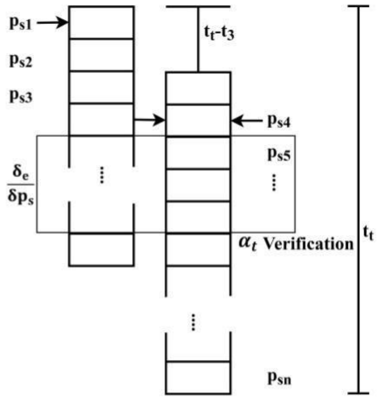
The simplest form of equation (5) is $(p_s t_t.\,e) = \alpha_t.\,(p_r.\,t_r)$. This does not remain the same until $e \ll p_r/p_s$, therefore, there are some cases in which $e = 0$[as in Figure 2(b)]. Therefore, the matrix resolution where $(p_s - p_r) \neq 0$ is observed in the transmission from 1 to $y$along t_t. In this case the approximation of errors is necessary to retain the sustainability of transmission. If the approximated error is different from the estimated error for is transmission, then the validity condition of $(p_s - p_r) > e$ is ensured for further transmission. If the mediate transmission is found to fail the condition, then the allocated $'a'$ is changed for the next successive transmissions. The approximation of e with respect to p_s is derived as

$$\frac{\delta_e}{\delta p_s} = \begin{cases} -2\sum_{i=1}^{y}\left[f_{ci} - \frac{\sum_{j=1}^{p_r} f_{cj}}{\Lsh}\right] = argmin\{e_1, e_2, \dots e_n\}, \\ RHS\ in\ equation\ (3), \forall\ (p_s - p_r) = 0 \\ 0, otherwise \\ 0 < e \leq 1, if\ (p_s - p_r) \neq 0 \end{cases} \tag{6}$$

The approximation considered in the above equation, if tends to0, then the transmission is pursued in the same arc. Similarly, if $argmin\{e_1, e_2, \dots, e_n\}$ is achieve, then transmission follows increased pause time to provide unanimous flows with less e. Instead, if $\frac{\delta_e}{\delta p_s} = 0 \leq e \leq 1$, then the transmission pursued by another arc $"a"$ where $e = 0$. The function for assigning $'a'$ is represented in Figure 3(a) and in 3(b) the scheduling process is represented.



3(a) Approximated Linear Function



3(b) Scheduling Process

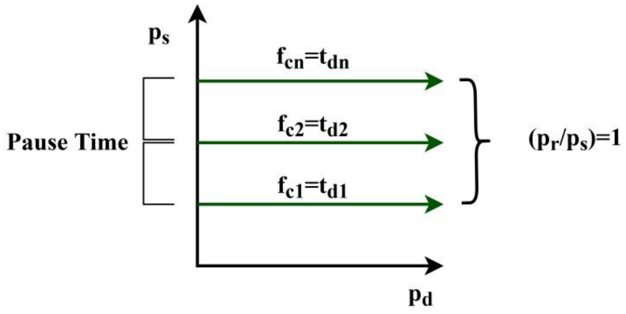
In this scheduling process, transmission loss along t_t is reduced by resolving the matrix approximation. Unlike the conventional methods that indulge in neighbor replacement at the end of transmission loss, this linear optimization identifies the variation in loss throughout the t_t. The variation in transmission is approximated using the linear function [as in Figure 3(a)] to decide upon changing $'a'$ (with $e = 0$) to pursue loss less flows. The advantage is that the capacity of the mesh network nodes is validated through the mediate transmission to determineit'sα_t in achieving successful flows. The process is unanimously adopted for any number of flows and packet size to control transmission errors. This would help to improve the number of successful flows delivered at the destination.

Scheduling based on ρ_t

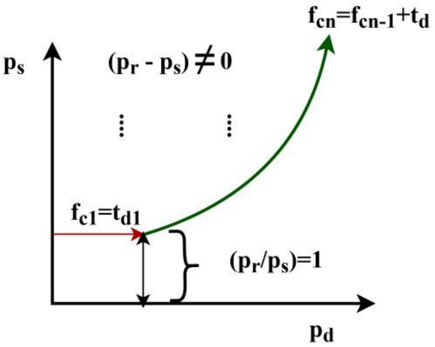
Another factorinfluencing the transmission and flow of the wireless nodes is the transmission probability. A node is said to exhibit busy and idle transmission probabilities depending on the availability of neighbors and bidirectional$"a"$. In particular, the bi-directional links of the neighbors must be congestion-free and idle at the time of selection. The idle probability of the node is the result of its previous transmission with its neighbors in $"a"$. In this consideration, the capacity of the link and the throughput rate for the transmitting packet is considered in the solution plane. The representation for the linear solution follows either of the throughput/link capacity. Let a_c represent the capacity of the arc that is given by the flow rate of the node (i.e.)$p_s \times t_t$. The throughput required by the network is the sum of all packets delivered at the destination (i.e.)$\sum_{p_s} p_s \times t_t \forall a \in n$. Contrarily, the rate of change in neighbors and their queue utilization influences their p_s over each transmission. Therefore, the difference in $(p_s \times t_t)$ and $(p_r \times t_r)$ is the stagnancy observed. The time delay is computed as

$$t_d = t_t + t_q + t_w \qquad (7)$$

Where, t_q and t_w are queuing and wait time respectively. This delay is nearly the same for all the$p_s \in \left({}^{p_r}/_{p_s}\right) \forall (p_r - p_s) = 0$. On the other hand, if $(p_r - p_s) \neq 0$, then the remaining flows are induced to experience an additional wait time/queuing time. The wait time is different from the enquiring time. The rate of flow determines the wait time of its successive transmission. Here, the error is considered as delay (i.e.) t_w for the remaining (enqueued) flows. The plane representation for the single factor of t_w is represented in Figure 4(a) and Figure 4(b) represents the solution with transmission constraints.



4(a) Optimal Transmission Condition



4(b) Delayed Transmission Condition

The linear function with respect to t_d in both the cases is simplified as in equation (8)

$$f_{cn} = \begin{cases} t_{dn}, \forall \left({}^{p_r}/_{p_s}\right) = 1 \& \ (p_r - p_s) = 0 \\ \sum_{i=1}^{y-1} \frac{t_{di}}{(y-1)} + (p_r - p_s) \times t_w, \forall (p_r - p_s) \neq 0 \end{cases} \tag{8}$$

The first $f_{cn}$is a normal/optimal condition where the delay is nominal. On the other hand, if f_{cn} relies on the previous transmission delays, then the linear segregation of t_d is analyzed. The case of queue management is completely exploited in optimizing this scheduling process. In addition to the ρ_t of a neighboring node, the queue utilization chances is also considered to achieve equation (1). The chance of queue utilization p_q is given by equation (9) as

$$p_q(p_s|n) = \begin{cases} p_s = p_r, \forall q_s \geq p_s \\ (p_s - p_r) \neq 0, \forall\ q_s < p_s \\ 0 \qquad\qquad ,\forall\ \ q_s = 0 \end{cases} \tag{9}$$

Where q_s is the queue size. The idle probability node experiences $q_s \geq p_s$or $q_s < p_s$. On the other hand, a busy transmitting node shows up $q_s < p_s$or$q_s = 0$. This results in addition t_w of the flow in the allocated transmission slot. Similarly, the end-to-end modelling of queue transmission based on acceptance rate ensures ρ_q of an ρ_t orρ_b node in a specific slot. Now, the linear resolution is given as

$$[p_s].\rho_t = \left(1 - \frac{q_u}{q_s}\right) \times \rho_q \times [p_r] \tag{10}$$

Where q_u is the queue utilization. The factor $\left(1 - \frac{q_u}{q_s}\right)$ determines the rate of packets flow, if $q_u = \ q_s$, and then though$\rho_t = 1$, $p_s \to 0$ as the queue is full. Therefore, t_w is experienced. The heterogeneous traffic cannot be modelled independently for each of the each of the nodes and therefore, the scheduling relies on the end-to-end queue transmission and acceptance rate of the neighbors. The rate of p_s is accepted in the consecutive neighbors as (p_{ra})

$$\left. \begin{array}{c} p_{ra} = \rho_q.(q_s - q_u) + \sum_{i=1}^{y}(p_{si} - p_{ri}).q_s\ \forall q_u = 0 \\ and \\ q_u.\rho_q = p_s \end{array} \right\} \tag{11}$$

If the acceptance rate of the neighbor is equal to p_s (i.e.) $p_{ra} = p_s$ then there is only t_q and if $p_{ra} < p_s$, then $(p_s - p_{ra})$ packet flows experience delay. This optimization therefore is modified from substituting p_s from equation (11) into equation (10),

$$\left.\begin{array}{c}[q_u \cdot \rho_q]\rho_t = \left(1 - \frac{q_u}{q_s}\right) \times \rho_q \times [p_r] \\ q_s[q_u]\rho_q \cdot \rho_t = (q_s - q_u)\,\rho_q[p_r] \\ q_s[q_u] = (q_s - q_u)[p_r]\end{array}\right\} \qquad (12)$$

From equation (12), two types of scheduling can be departed as $(q_s - q_u) = 0$and $(q_s - q_u) > 0$. Therefore, the linear optimization follows

$$\left.\begin{array}{c}\sum_{i=1}^{y} p_r + \sum_{i=y+1}^{t_t}(q_s - q_u) \cdot \rho_t \\ for\ all \\ t_d = t_t + t_q + (q_s - q_u) \times t_w\end{array}\right\} \qquad (13)$$

This transmission follows concurrent scheduling of flows through different neighbors. The transmission follows 1 to y through one neighbor and $(y+1)$ to t_t transmission through the other neighbor. This neighbor must possess both $\rho_q = 1$ and $\rho_t = 1$ to ensure delay less transmission.

4. RESULTS AND DISCUSSION

The proposed DTS-QM is analyzed through simulations performed using Opnet Modeler.The network is configured with 100 nodes moving in a random manner. The impact of velocity is less considered and hence it is assigned as 20m/s for all the 100 nodes. The detailed simulation factors and its values are presented in Table 1.

Table 1 Simulation Factors and Values

Factor	**Value**
Network Dimension	1000m× 500m
Nodes	100
Basic Data Rate	1Mbps
Slot Time	20µs
Flows	2-12
Packet Size	400-750 bytes
Pause Time	2ms
Slots/ Node	30

The performance is analyzed using throughput, delay, queue time, packet loss, and slots. For a comparative analysis, the existing MinCosRO [17], JRS-SM [16], and RCA-HRP [15] are preferred for the same metrics.

Throughput Analysis

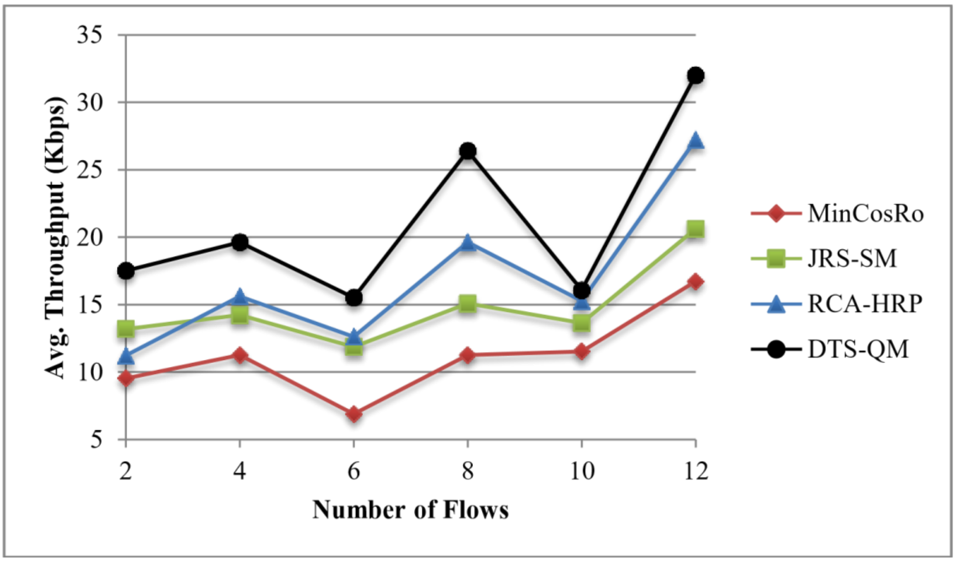


Figure 5(a) Throughput versus Flows

In Figure 5(a) and 5(b), the average throughput achieved in the mesh network using DTS-QM and the existing methods are compared. The comparison is preceded with respect to the varying flows and packet size. With respect to the flows and packet size, the objective of the proposed method is to maximize the flows. In the independent analysis of transmission with respect to α_t and ρ_t, transmission loss (packet drop) and delay are validated using the linear form respectively.

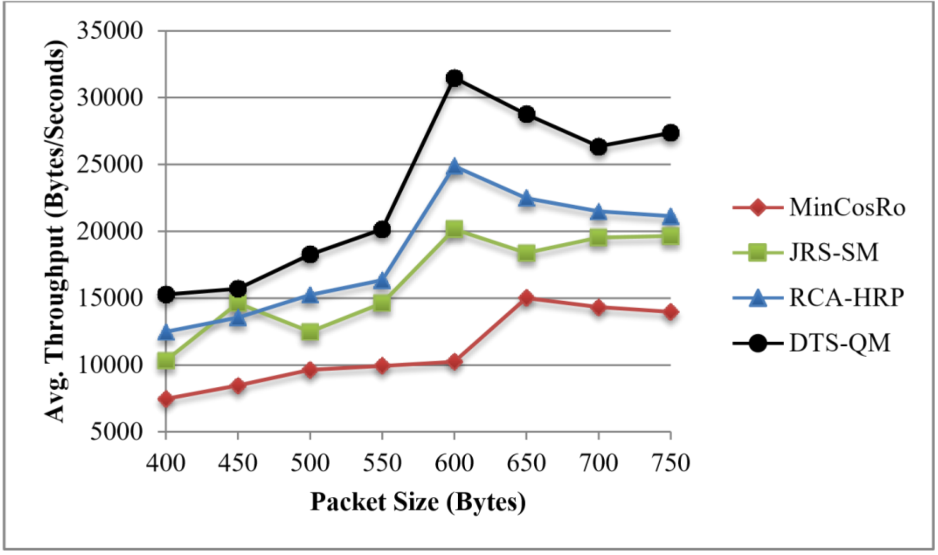


Figure 5(b) Throughput versus Packet Size

The linear representation of the constraints and the transmission factor helps to differentiate the transmission in t_t. The errors with respect to packet drop and queue overloading are addressed by identifying constraint based neighbors in the successive and recurrent scheduling process. Therefore, neighbor selection constraints and arc selection is unanimously adapted throughout the transmission process ensure better flow being delivered at the destination. This increases the throughput of the network irrespective of the varying flows and packet sizes.

Delay Analysis

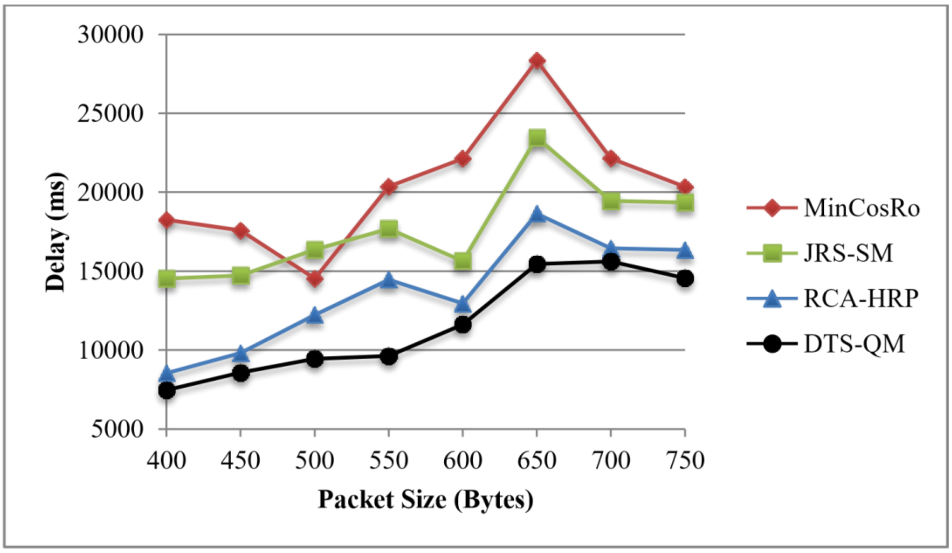


Figure 6 Delay versus Packet Size

The delay causing constraints in the network are due to retransmission and additional wait time experienced in flow transmission. In the proposed scheduling method, the errors in flow transmission are thwarted using the linear differentiation. In this differentiation, the retransmission attempts are greatly reduced by selecting optimal neighbors for communication. In the flow based queuing process, the nodes that satisfy equation (11) and (12) are alone admitted for participating in transmission process. Therefore, selected nodes ensure less waiting time and concurrent transmission that permit less delay in the proposed DTS-QM method (Refer Figure 6).

Queue Time Analysis

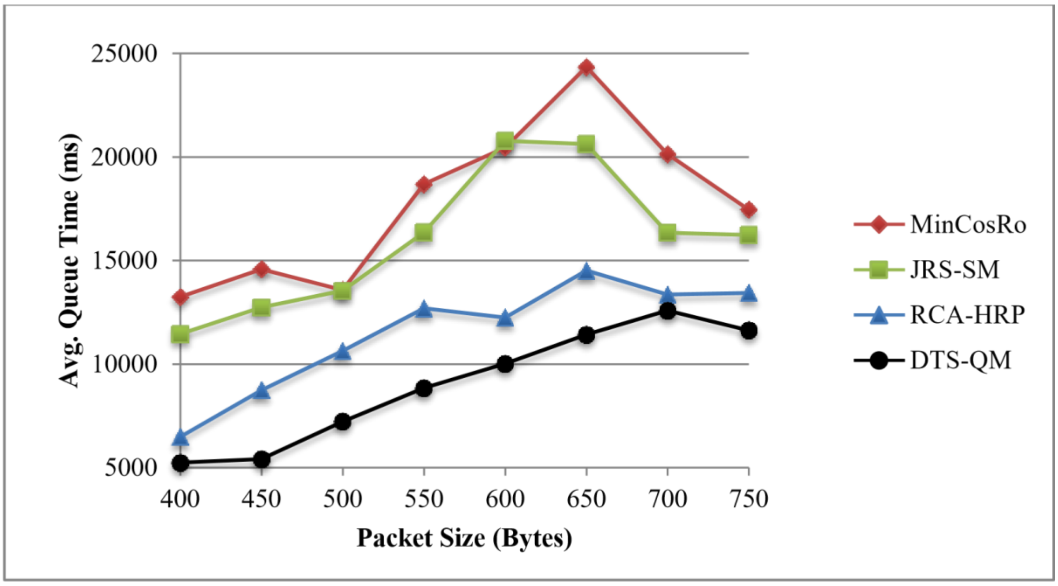


Figure 7 Queue Time versus Packet Size

Figure 7 presents a comparative analysis of queue time between the existing and proposed methods. In the proposed DTS-QM, queue acceptance rate is assessed for the incoming flows in the network. If the equation (10) to (12) are balanced by the selected and current transmitting node, then the flows are sent to the neighboring nodes. This transmission follows either queue or loss less neighbor selection due to which the queues are operated in a concurrent manner. This helps to reduce the queuing time of the incoming flows irrespective of the size of packets experienced in different traffic patterns.

Packet Loss Analysis

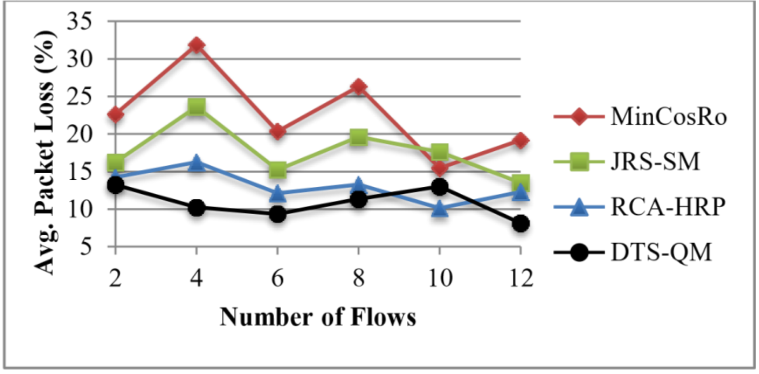


Figure 8 Packet Loss versus Flows

In the process of validating transmission on the basis ofα_t, the neighbors are selected on the basis of less transmission errors. The transmission errors are measures on the basis of the packet loss experienced by the nodes. The linear optimization for neighbor selection schedules transmissions for both the RHS and LHS conditions in equation (3), permitting optimal neighbor selection. The approximation of error with respect to the flow determines the validity of$(p_s - p_r) = 0$ for the RHS part in equation (3). However, the variation of flows recommends neighbor selection such that equation (1) is achieved by reducing the packet loss due to the transmission classification.

Slots Analysis

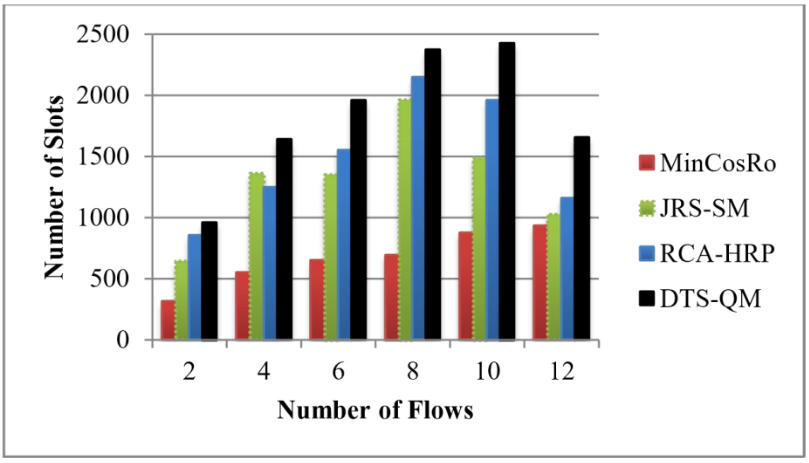


Figure 9 Slots versus Flows

Figure 9 illustrates the comparative analysis of the slots utilized by the existing and proposed methods. The transmission in the proposed method is seamlessly persuaded by selecting loss less and queue optimized neighbors along the communication process. This helps to maximize the capacity and queue utilization of improve the need for communication slots. Therefore, the optimization performed independently for the transmission factor and queue management for all the transmitting nodes, the slot requirement of the proposed method is high. Table 2 presents the values of the comparative analysis of the above metrics.

Table 2 Comparative Analysis Values

Metrics	**MinCosRO**	**JRS-SM**	**RCA-HRP**	**DTS-QM**
Avg. Throughput (Kbps) vs Flows	16.724	20.614	27.236	32.014
Avg. Throuhgput (Kbps) vs Packet Size (bytes)	13965	19633	21116	27356
Delay (ms)	20347	19362	16356	14572
Avg. Queue Time (ms)	17462	16247	13447	11632
Avg. Packet Loss (%)	19.19	13.52	12.31	8.14
Slots	929	1024	1156	1652

5. CONCLUSION

In this article, distributed traffic scheduling with dynamic queue management is introduced for improving the QoS of WMNs. The proposed method is keen in classifying the traffic based on transmission errors for scheduling and adapts dynamic queue management for handling packets of varying sizes. The process of optimization is led by linear optimization for addressing the transmission constraints and assigning communication schedules. The assimilated methods reduces the packet drop and queuing delay in WMNs, improving network throughput and better utilization of the communication slots.

Bibiliography

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