An Efficient Bandwidth Management Framework for Wireless Mesh Networks

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ABSTRACT: *Wireless mesh networks (WMNs) offer dependable and scalable solutions for services utilizing large bandwidth. Enhancement in the deployed number of applications based on wireless mesh networks necessitated a corresponding increased demand for higher bandwidth. This paper proposes a framework for effective management of bandwidth in WMNs making use of the concepts of cross layer design and ant colony methods.*

Keywords: Bandwidth Management, Cross Layer Design,WMN, QoS etc

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1. Introduction

A wireless back bone in conjunction with mesh clients comprises the architecture of Wireless Mesh Network (WMN) [1-3]. The back bone itself is built up of mesh routers and gateway nodes, which provide internet connectivity by forming the back-haul links. The mesh clients here could be mobile or stationary. The back bone can offer services to a variety of networks such as cellular networks, wireless sensor networks, WLANs, ad-hoc networks and mobile ad-hoc networks (MANETs). The credentials of WMNs are established in providing last mile access to several services. Though the mesh routers can be mobile also, in this paper we restrict into just considering the largely used network structure as infrastructure/back bone mesh network, for instance as used in community networks [1].

In sharing a scarce resource like Wireless bandwidth [4- 14], several wireless nodes in the adjacent neighborhood compete with each other, where some nodes are deprived of enough bandwidth to support their service requirements,while some other dominate the channel. So, the bandwidth management [7, 8] is to be ensured through proper mechanism, for optimal utilization of bandwidth. It involves the processes such as estimating the available bandwidth, proper channel allocation, reducing unwanted traffic, wireless channel monitoring, adapting the flow and rate and furnishing QoS guarantees [14, 15].

Different characteristics of the channels, allocation of bandwidth and levels of fault tolerance are some of the major challenges encountered in providing QoS in wireless networks. Each of the layers such as physical, MAC, IP, TCP and application, has its own mechanism of providing QoS. Such networks, where each individual layer providesQoS guarantee, are more flexible and more tolerant to issues of QoS. In cellular networks, the role of bandwidth in furnishing QoS is significant. Efficient allocation of bandwidth is pivotal due to its limited availability. The issue becomes all the more complex when support is to be extended to different kinds of traffic such as real time and non-real time. The requirements are diverse and need to be addressed properly.

Delay-sensitive real time traffic requires immediate response while the non-real time traffic expects fault-free packets, as it is more sensitive to loss of data than to delay. These crucial factors need to be considered while providing QoS for real time and non-real time traffic. [7, 8, 16-22].

This paper proposes QoS Aware Cross Layer based Bandwidth Management (QCBM) frame work for imparting bandwidth management to different services of WMN efficiently. The advantages of both the cross layer design and ant colony optimization are incorporated into our framework. The methods are so implemented that the proposed framework consequently saves bandwidth.

The organization of the rest of the paper is as follows: Section II is ear marked for the related work accomplished in this area. Our proposed framework is explained in Section III. Section IV displays illustrations of the proposed framework. Our approach is compared to some other existing approaches in Section V. Section VI wraps up the paper enlisting the future work.

2. Related Work

In spite of considerable work presented for ad-hoc networks, cellular networks etc, it is observed that WMN is fast gaining popularity as the ideal technology most suited for future services and applications. Significant quantity of research and exploration are still needed to address the challenging demands in this area. Several works in the past have considered different aspects in WMNs such as routing, allocation of resources, multicasting, control of congestion etc. [2-5]. Wei et al [2] propose SRAM framework, a light weight bandwidth management scheme. De-Nian Yang et al. [3] discuss the means and measures of policies of efficient allocation of resources rooted on multicasting techniques for WMNs. K. Nahrstedt et al. [4] present a framework utilizing cross layer design methods for the management of bandwidth. QoS issues arising out of evolving an efficient bandwidth management scheme for WMNs are described by M. Iqbal et al. [5].

For MANETs, P. Venkata Krishna et al.,[7] [16] propose a cross layer QoS model called CLIASM [Cross LayerInteraction and Service Mapping]. This model proposes information sharing through a forward and backward flow mechanism. Though the

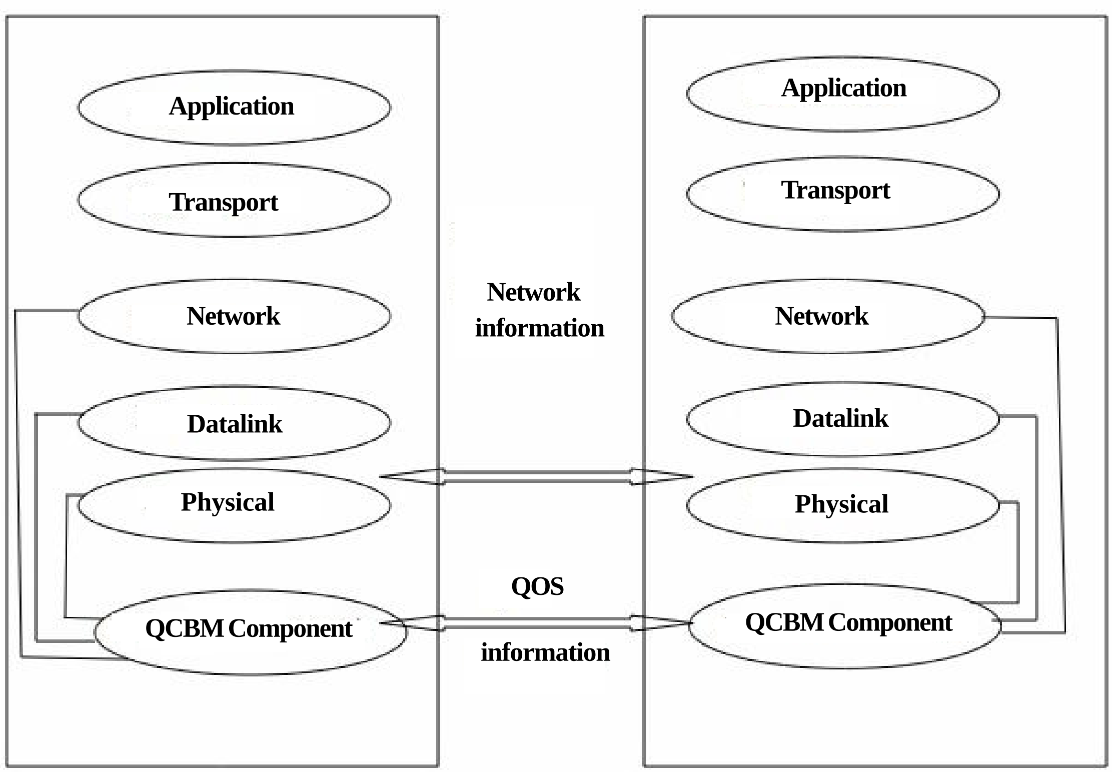

Figure 1. QCBM System

individual layers have different functions to perform, utilizing a shared database enables information sharing among layers. Creating two interfaces between two layers enables a two-way flow of information. Implementation of the model is based on the way network features are divided according to layers as Application Layer Metrics (ALM), Transport Layer Metrics (TLM), Network Layer Metrics (NLM) and MAC Layer Metrics (MLM). But it is to be noted that the deployment of these cross layering approaches could trigger unintended interactions and side effects

We present a framework called as QoS Aware Cross Layer based Bandwidth Management (QCBM) in this paper. Here, we intend using concepts of cross layer design and ant colony optimization. The performance of our approach form enhanced packet delivery and end-to-end delay has been estimated.

3. System Model

The framework proposed by us, namely, QoS Aware Cross Layer based Bandwidth Management (QCBM) in WMN is constructed on some principles presented in the paper [6-7], [16], [19] and [22].

3.1 Network Model

A WMN can be represented as a graph W = (V, E), where V is the set of vertices and E the set of edges. Vertices of the graph represent nodes and edges represent the link between the nodes. Path in the network is set of vertices connected to each other from one vertex to another. All links in the network are bidirectional, i.e., if $(v_i, v_{i+1}) \rightarrow E$, then $(v_{i+1}, v_i) \rightarrow E$ also exists. Faults in the network are independent of path and can occur randomly. Each node has two components: a routing component and a QoS component. Each node's QoS component is independent of others and shares updates through CLIASM mechanism. Figure 2 shows, CLIASM component sharing the information with neighboring nodes. For each link $e \in E$ the QoS metrics associated with it are *bandwidth* (*e*) and *delay* (*e*) and *hop count metric* for the whole path. Similarly *bandwidth* (*e*) represents the available bandwidth of the link *e* and *bandwidth* (*path* (*i, j*)) represents the bandwidth available for the entire path from *i* to *j*.

3.2 Cross Layer Design

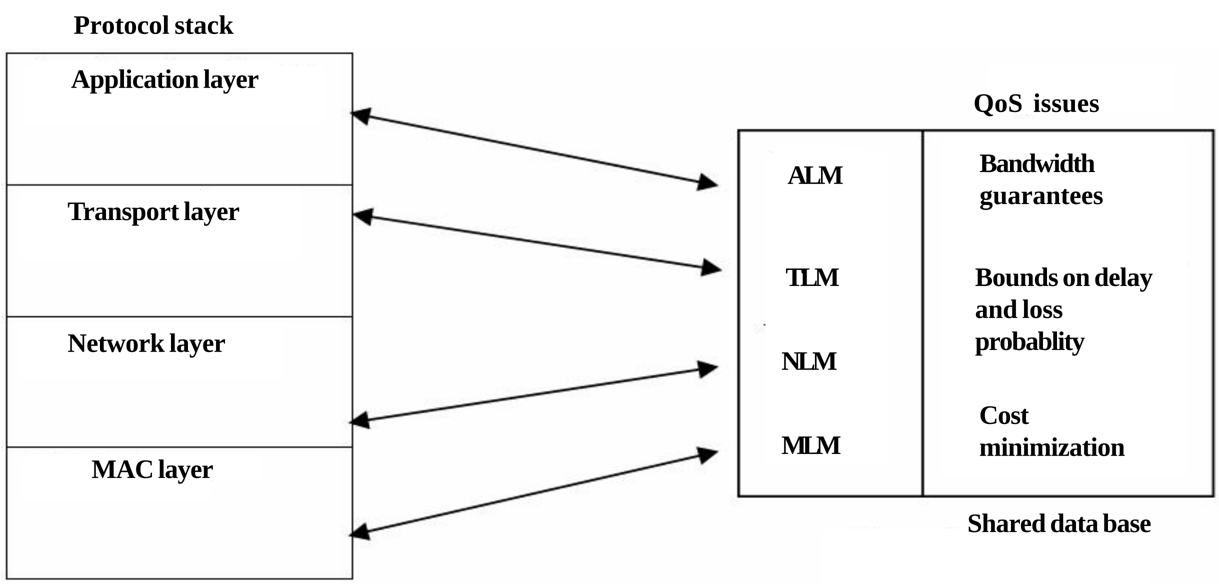

Figure 2. Cross layer design component [6-7]

A cross layered design approach is used in the routing component of QCBM. Information from physical, data link and network layer is used for taking routing decisions as displayed in Fig. 1. The framework accomplishes this by utilizing a data structure containing the shared fields among the three layers as illustrated in Table.1, which contains the parameter of shared data structure and its type. In the event of the user having a specified threshold for QoS parameters,then it is desirable to discover the goodness of the path through QoS metrics.

Parameter	Type
Trust Pheromone value	Float
QoS factor	Float
Hop count	Integer

Table 1. Shared data structure

Considering all the aspects emphasized in the paper [11], we propose the QCBM framework for efficient management of bandwidth in WMN.

4. QoS Aware Cross Layered Bandwidth Management Framework

The primary focus of the proposed scheme is to envisage multiple disjoint paths to destination addressing therequirements of QoS. The proposed frame work of QoS Aware Cross Layered Bandwidth Management (QCBM)utilizes a multipath QoS enabled routing protocol developed on the model of foraging behavior of ant colony. The principle is, the source generates the ant agents (called reactive forward ants) for the purpose of finding multiple paths to the destination, and backward ants return to set up the paths. Pheromone tables reflect the respective quality of the paths. The metric of Next Hop Availability (NHA) is considered for estimating the goodness of the links and nodes having high availability during the route discoveryphase. Here, the source first checks for the trusted adjacent node when it wants to send information to a destination node. The subsequent step is the selection of the nodes having greater next hop availability than the threshold. Finally, the source node broadcasts Forward Ant (FANT) to all its already checked adjacent trusted nodes having $NHA > NHA_{thr}$ in such a way that the routing overhead is controlled.

The basis of ACO [Ant Colony Optimization] heuristic is the representation of the generic problem and definition of the behavior pattern of ants. For this, ACO adopts the real ants' foraging behavior. In the presence of multiple available paths from nest to food, ants perform an initial random walk. During such forward trips to food andreturn trips to nest, they route-mark the path they have used, by laying a chemical substance called pheromone. Newer ants would subsequently prefer the more used paths with higher concentration of pheromone and in the process also reinforce the path they have used. Consequent to this autocatalytic effect, the solution emerges quickly [6].

System Strategy:

1. Initialize all parameters of shared data
2. For all requests do the following
   a) estimate no. of paths between the source and destination nodes
   b) Find the optimal path using ACO and QoS threshold value
3. Update the shared data of cross layer database

4.1 Node Identification Process

The process of identifying the node is adopted from [19] i.e. HTNI (Hash Table Node Identification) method with some alterations. As in [19], the network is separated into cells but here, every individual cell is managed by a Backbone Router (BR). The assumption here is that the mesh routers are situated in such a way, that they stand connected to the adjacent mesh routers, but the cells individually managed by them remain non-overlapping. This way, a mobile node belongs exclusively to one region or cell. The respective BR manages the mobile nodes under a cell. But these BRs need to maintain the movement track of the mobile nodes, which belong to its region.

The BR keeps track of the locations of its mobile nodes and also checks such mobile nodes which are alien to its cell. In the event of a BR receiving a data packet to be forwarded to its mobile nodes, particularly when they move to some location else, the BR dispatches a node search request (NSREQ) packet to the mesh routers in the proximity for tracing the current location of its mobile nodes. This packet contains the IDs of BR, of the destination mobile and of the sequence of the packet. On locating the destination mobile node by some mesh router i.e. if the node in search is within the cell of the specific mesh router, that mesh router responds by sending its own router ID in the node search reply (NSREP) packet to the BR, which started the process of search. Then, through the network of backbone, the BR forwards the packet to that specific identified mesh router. The received multicast data packet in turn is forwarded to the concerned node by the destination mesh router. The BR maintains the track of all its mesh nodes belonging to the same multicast group by storing their last identified location.

Individual mesh routers are given unique IDs for identifying each other. IDs are also provided to the mobile nodes, calculated on the basis of their BR's IDs using HTNI method [19].

Then, applying HTNI [19] calculation, the source mesh router extracts the router ID of the BR., containing the destination mobile nodes from the IDs of destination mobile nodes. Then, using the optimal path through QCBM strategy, the packets are routed to that BR. Once the packets reach the respective BRs, they are forwarded to the destination mobile nodes.

5. Performance Evaluation

The metrics listed below are utilized for an estimation of the performance of the proposed QCBM mechanism:

• Packet Delivery Throughput: This can be explained as the quantity of received data packets at the destinations corresponding to those dispatched by the CBR sources.

• End-to-End Delay of Data Packets: This can be defined as the delay in time between the packet originating time at the source and its reaching time at the destination. Lost data packets enrooted are not taken into consideration. But the delay metric takes into account the delays arising out of route discovery, queuing and retransmission.

An evaluation of the performance of our approach was done by comparing and juxtaposing against that of CLIASM [7]. It is explicit from the results as shown in Figure 3 and Figure 4, that the performance of the proposed system is much improved in comparison to the existing methods.

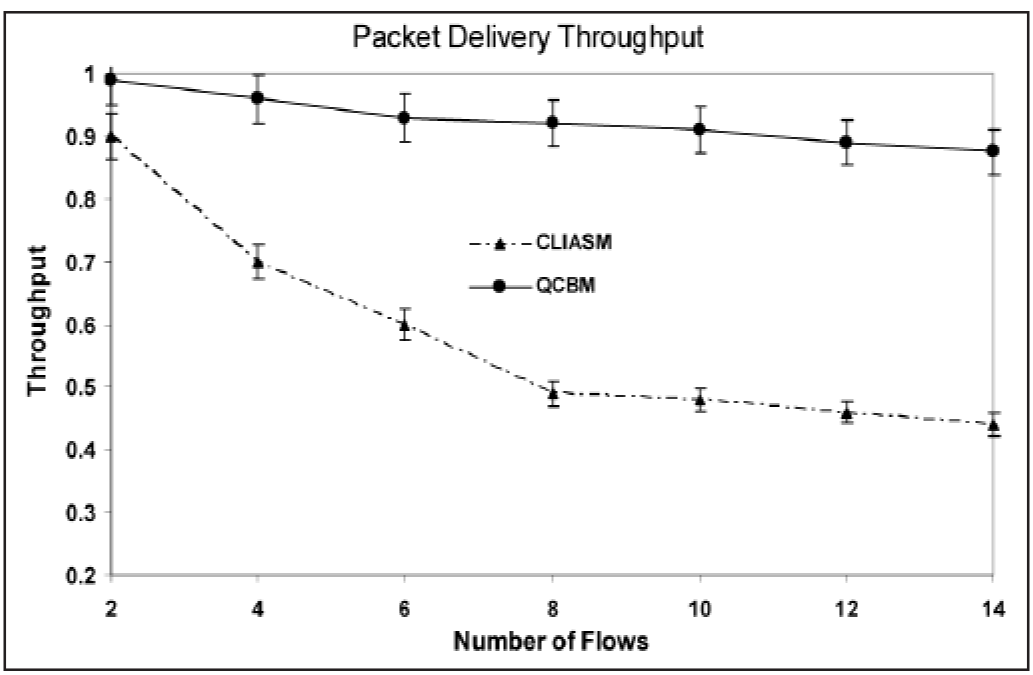

Figure 3. Packet Delivery Throughput analysis

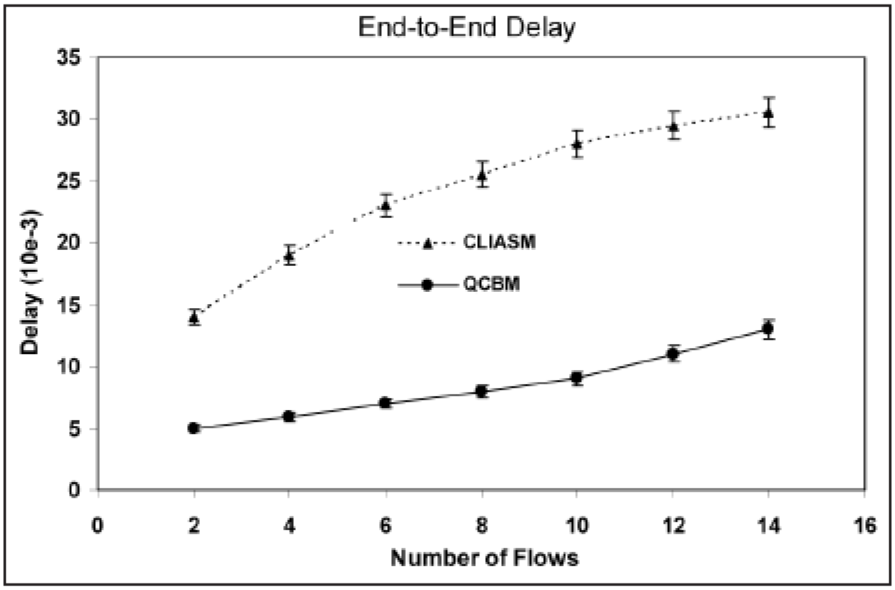

Figure 4. End-to-End Delay analysis

6. Conclusions and Future Work

A framework called QoS Aware Cross Layer based Bandwidth Management (QCBM) is presented in this paper. The efficacy of the proposed system is estimated through introduction of shared data structure of cross layers. During the route discovery process, the approach based on the foraging behavior of ant colony provides efficient utilization of available multiple paths. HTNI methods are adopted by the mesh routers for locating the mobile nodes when such nodes shift their locations from one BR to another.

We plan to extend this framework in future to include media access protocols, which can consider cross layer interactions to provide QoS guarantees for real timeapplications. We also intend to develop algorithms for efficient flow and control of congestion to maintain the network stable even during instances of very high loads on the network.

Appendix

The metrics Delay and Bandwidth from a node *i* to an arbitrary node *j* are calculated [6] as

$$Delay\ (path\ (i, j)) = \sum_{e \in p(i,j)} delay\ (e) + \sum_{n \in p(i,j)} delay\ (n) \qquad (1)$$

Here delay is an Addictive metric, and Bandwidth is a concave Metric.

$$bandwidth\ (path\ (i, j)) = \min_{e \in p(i,j)} \{bandwidth\ (path\ (e)\} \qquad (2)$$

Here bandwidth is a concave metric and end-to-end delay, hop count are additive metric. Bandwidth metric is used to specify the amount of available bandwidth along the path from the source to the destination.

$$Hopcount\ (path\ (i, j)) = Number\ of\ nodes\ in\ a\ particular\ path \qquad (3)$$

Since multiple hops are involved in the transmission of data from source to destination in WMNs, hop count is considered as an important metric [6].

If the user has a particular threshold for QoS parameters, then it is desirable to trace and identify the goodness of the path by using the QoS metrics. Let D_T, B_T and H_T be the threshold values for delay, bandwidth and hop count values respectively and D_C, B_C, H_C are calculated delay bandwidth and hop count QoS metrics respectively along the path from source to destination then for each FANT received the paths should ensure that $D_C < D_T$, $B_C > B_T$, $H_C < H_T$. It is important at this juncture to discover the best path by finding the path preference probability for the paths which satisfy the constraints of the QoS. These can be calculated on the basis of estimation of the goodness values of QoS parameters along the path. The goodness of the QoS metrics is assessed by arriving at the percentage of their deviations from the threshold values. Let d_g, b_g, and h_g be the delay, bandwidth and hop count goodness values and are calculated as follows:

$$d_g = \frac{D_T - D_C}{D_T} * 100 \tag{4}$$

$$b_g = \frac{B_C - B_T}{B_C} * 100 \tag{5}$$

$$h_g = \frac{H_T - H_C}{H_T} * 100 \tag{6}$$

The path preference probability P (*i*) for the path *i* can be calculated by using the above parameters as indicated below:

$$P(i) = \frac{(d_g * b_g * h_g)_i}{\sum_{j \in p_i} (d_g * b_g * h_g)_j} \tag{7}$$

Where, p_i is set of paths, explored during the route discovery phase from source to the destination.

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