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# CROSS-LAYER BASED QOS ROUTING (CLBQR) PROTOCOL ANALYSIS BASED ON DATA FLOW FOR 802.16 WIMAX NETWORKS

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**ABSTRACT**

*Cross-layer design for quality of service (QoS) in WiMax has attracted much research interest recently. Such networks are expected to support various types of applications with different and multiple QoS and grade-of-service (GoS) requirements. In order to achieve this, several key technologies spanning all layers, from physical up to network layer, have to be exploited and novel algorithms for harmonic and efficient layer interaction must be designed. Unfortunately most of the existing works on cross-layer design focus on the interaction of up to two layers while the GoS concept in WMNs has been overlooked. The research on traditional cross- layered architecture which has served well for wired networks seems to be inefficient and not suitable for the wireless networks. Most of the cross-layer design proposals for wireless networks involve exchanging information between multiple layers or between just two layers. In this paper, we propose to develop a Cross-Layer Based QoS Routing (CLBQR) Protocol for 802.16 WiMAX Networks. In our protocol, the cross layer routing is based on the routing metrics which includes power, link quality and end-to-end delay. Then the routing is performed by estimating the combined cost value of these metrics. By simulation results, we show that our proposed protocol achieves higher packet delivery ratio with reduced energy consumption and delay.*

***KEYWORDS:*** *QOS, GOS, WiMax, CLBQR, AODV Protocol, EETT (Exclusive Expected Transmission Time).*

## I. INTRODUCTION

### 1.1 WiMAX Networks

WiMAX (Worldwide Interoperability for Microwave Access) is a telecommunications protocol that provides fixed and fully mobile internet access. Wi-Fi, refers to interoperable implementations of the IEEE 802.11 and is similar to the WiMAX which refers to interoperable implementations of the IEEE 802.16 wireless-networks standard. The vendors can sell their equipments as WiMAX certified by using the WiMAX Forum certification. Hence it ensures a level of interoperability with other certified products, as long as they fit the sample profile [1]. A typical wireless mesh network scenario as shown in figure 1.

For providing mobile broadband or home broadband connectivity, companies use WiMax across whole cities or countries. WiMAX network has relatively low cost when compared to the GSM, DSL, or Fiber-Optic. Due to this broadband connection can be provided in places where it is not economically possible. Cellular phone technologies such as GSM and CDMA are replaced by WiMAX or can be used as an overlay to increase capacity [1].

WiMAX is concerned as a disruptive wireless technology with many impending applications. With the QoS support it is probable for WiMAX to support business applications. WiMAX network can work in different modes point-to-multipoint (PMP) or Mesh mode, depending upon the applications and network investment [2].

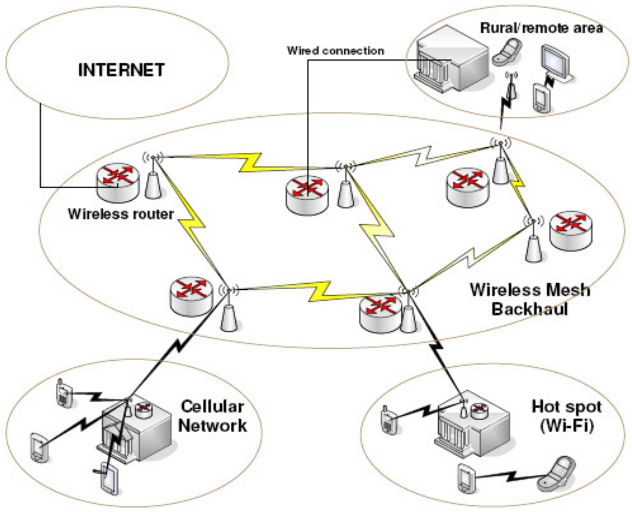


**Figure 1.** Typical Wireless mesh network Scenario

### 1.2 Routing types in WiMAX networks

There are two basic mechanisms for routing in the IEEE 802.16 mesh network

- Centralized routing
- Distributed routing

**Centralized Routing**

In mesh mode concept, BS refers to the station that has directed connection to the backhaul services outside the Mesh Network and the remaining stations are termed as SSs. There are no downlink or uplink concepts within the Mesh Networks. However a Mesh network performs like PMP with a variation that all the SSs should not be connected directly with the BS. The resources are approved by the Mesh BS and this is considered as centralized routing [1].

**Distributed Routing**

In distributed routing, with the help of its adjacent nodes each node receives some information about the network and it used to forward the traffic of each router. The BS is not defined appropriately in the network when using the distributed routing [1].

### 1.3 Routing Issues in WiMax Networks

The following are some of the routing issues in wimax networks:

- Routing in Wireless Mesh Network (WMN) is challenging because of the unpredictable variations of the wireless environment.
- Challenges for the routing in WiMax mesh includes delay, long transmission scheduling, and increasingly stringent Quality of Service (QoS) support and load balance and fairness limitations [3].
- The network topology in an 802.16 standard is a tree rooted at the base station and the problem is to determine the routing and link scheduling for the tree, either jointly or separately.
- Routing design has to address issues in both short and long time scales [3].
- WiMAX networks also face all the problems related to the hostile wireless environment, where power constraints make it difficult to provide hard QoS guarantees**.**
- While the Base Station can have continuous, unlimited power supply, other nodes usually have limited power supply and are battery-powered. It is inconvenient to replace them once they are deployed. Sometimes, replacement is even impossible. Thus, energy efficiency is a critical design consideration of WiMAX networks.
- Communication is a dominant source of energy consumption in WiMAX networks.
- Security is one of the main barriers and is crucial to wide-scale deployment of WiMAX networks, but has gained little attention so far. Once a node has been compromised, the

security of the network degrades quickly if no measures are taken to deal with this event. Other security concerns may include the location privacy of a person, passive eavesdropping, denial-of-service (DoS) attacks, and so forth.

- Nodes energy cannot support long haul communication to reach a remote command site and hence they require multi-tier architecture to forward data. It is a fact that 70% of the energy is spent in data transmission [4].
- Wireless routing also has to ensure robustness against a wide spectrum of soft and hard failures, ranging from transient channel outages, links with intermediate loss rates, from several channel disconnections, nodes under denial-of-service (DOS) attacks, and failing nodes.
- A good wireless mesh routing algorithm has to ensure both long-term route stability and achieve short-term opportunistic performance

### 1.4 Cross Layer Routing

The joint optimization control of over two or more layers in a cross-layer paradigm provides considerably improved performance. Cross-layer design for quality of service (QoS) in wireless mesh networks (WMNs) has attracted much research interest recently. Various types of applications with different and multiple QoS and grade-of-service (GoS) requirements can be supported with these networks. Several key technologies spanning all layers, from physical up to network layer should be utilized for supporting the QoS and GoS. In addition to this, essential algorithms must be designed for harmonic and efficient layer interaction [5].

In our previous work [11], we have proposed a channel condition based rate allocation method which takes into account the channel error. It consists of two phases; Admission Control Phase and Rate Control Phase. In the first phase, the admission control is performed based on the estimated channel condition. In the second phase, we have developed a predictive rate control technique, using queue length and bandwidth requirement information.

Hence our objective is to design an efficient cross-layer based routing protocol for 802.16 WiMAX networks. In this paper, we develop a cross-layer based QoS outing protocol. In this protocol, using the physical and MAC layer, the minimum required power and link quality can be estimated and passed on to the routing layer. Then a combined cost value of the link quality and power along with delay can be determined and used in the routing protocol.

## II. RELATED WORKS

Chi Harold Liu et al [5], proposed Cross-Layer Design for QoS in Wireless Mesh Networks. They proposed a novel cross-layer framework that includes connection admission control together with QoS routing in the network layer and distributed opportunistic proportional fair scheduling in MAC layer. They defined a novel utility function that is exchanged between an efficient distributed opportunistic proportional fair scheduler and a multi-constrained QoS routing algorithm. Furthermore, a novel tightly-coupled design method for joint routing and admission control has been demonstrated, where a unified optimization criterion QoS performance index" that combines multiple QoS constraints to indicate the QoS experience of each route has been proposed.

Ali Al-Hemyari et al [6] proposed Cross Layer Design in 802.16d.The cross layer design discussed by them is dealing with the exchangeable information between MAC and NET layers to optimize the system performances. Two routing algorithms to find the scalable path to the BS for each node, and two CS algorithms for single and multi-channels single transceiver system have been proposed by them. Some related issues pertaining to the system improvement are load balancing and fairness, slot reuse, concurrent transmission, and the relay models in the network also have been discussed. The system performances are further improved when a new design metric such as number of children per nodes is introduced.

Chun-Chuan Yang et al [7] proposed, Cross-Layer QoS Support in the IEEE 802.16 Mesh Network. Core mechanisms including mapping of IP QoS classes to 802.16 QoS types, admission control, minimal-delay-first route selection, tag-based fast routing, and delay-based scheduling were presented in the paper. This proposal can achieve the better performance in terms of delay, throughput, and signaling cost over the basic centralized and distributed scheduling scheme recommended in the standard.

Taimour Aldalgamouni et al [8], proposed a joint cross layer routing and resource allocation algorithm for multi-radio wireless mesh networks. The cooperation between the physical, MAC and network layers improved the performance of the network. The results showed that the proposed algorithm improved the average end to end delay and average end to end packet success rate compared to those of random routing and random resource allocation.

Fei Xie et al [9], proposed a cross-layer framework for video-on-demand service in multi-hop WiMax mesh networks. They aim at supporting true VoD service in residential or business networks with a WiMax based wireless backhaul. Their proposed routing algorithm makes use of the well-maintained scheduling tree and thus introduces less maintenance cost. The algorithm also minimizes the cost of joining a multicast tree. Based on the multicast routing algorithm, they applied the application layer patching technique which can offer true VoD service. They also extend the joint admission control and channel scheduling scheme to guarantee the data rate for Patching.

# III. ESTIMATION OF ROUTING METRICS

In this section, we briefly explain the routing metrics used in our cross layer based routing protocol. We use the following metrics:

- Power (P)
- Link Quality (LQ)
- End-to-End Delay (D)

### 3.1 Power

For utilizing the bandwidth efficiently, power control is very important. A Large number of hops are used in each route if the power allocated for each hop is minimum. Delay share of each hop can be decreased and thus it requires more time slots (bandwidth). On the other hand, in every route there are a minimum number of hops if maximum power is allocated. But the number of simultaneous transmissions is limited by the increase in the interference which leads to the inefficient wireless bandwidth utilization. In order to realize QoS provisioning with efficient resource allocation an optimal power allocation is required. *Pmin* is the minimum power required to transmit a signal on a link given the link distance and the sensibility of the receiver. *Pmax* is the maximum transmission power.

### 3.2 Link Quality

Links which are nearby with higher link quality can be allowed to transmit more packets, if links with poor quality is avoided by hopefully waiting for the link to improve. This probably improves the quality of the link. If the link behaves normally then the poor quality link could try to communicate.

We use the EETT (Exclusive Expected Transmission Time) metric to estimate the link quality [10].

EETT is a routing metric which is used to give a better evaluation of a multi-channel path. Consider a N-hop path with K channels. We have following definitions. For a given link l, its Interference Set (IS) is defined as the set of links that interference with it. A link’s Interference Set also includes the link itself. Then the link l’s EETT is defined as:

$$EETT_i = \sum_{link\ i \in IS(l)} ETT_i$$

where IS(l) is the Interference Set of link l.

### 3.3 End-to-End Delay

The delay associated with a network path is the sum of delays experienced by the links constituting the path and hence end-to-end delay is considered as an additive metric. The distance taken for a bit of data to travel across the network from one node to another is known as the delay and is usually calculated in multiples or fractions of seconds. Depending upon the location of the specific pair of communicating nodes, slight variations in the delay occurs. The maximum and average delay is necessary to perform exact measurements.

Each route *r* has a maximum end-to-end delay requirement to each of its packets. The end-to-end delay of a packet is the time it takes to travel from the source node to the destination node including intermediate links' transmission delays and nodes' queuing delays. Each link transmission delay equals the reciprocal of the link bandwidth (data transmission rate) which is constant. For the estimation of queuing delay, we use the average queuing delay at each node. Therefore the end-to-end delay D is given as,

$$D = \sum_{i=1}^{n} \frac{1}{LBW} + AQ_D$$

where LBW is the link quality bandwidth and $AQ_D$ is the Average Queuing Delay.

# IV. CROSS LAYER BASED QOS ROUTING (CLBQR) PROTOCOL

## 4.1 AODV Protocol

Our cross layer based routing is a derivative of the well known AODV routing protocol. In this section, we briefly explain the working of the AODV protocol.

Ad-hoc On-demand distance vector (AODV) is a variant of classical distance vector routing algorithm. AODV uses a broadcast route discovery algorithm and then the unicast route reply massage. The following sections explain these mechanisms in more detail.

### 4.1.1 Route Discovery

A route discovery process is initiated, when a node wants to send a packet to some destination node and does not locate a valid route in its routing table for that destination. Route request (RREQ) packet is broadcasted from source node to its neighbor, which then forwards the request to their neighbors and so on.

An expanding ring search technique is used by source node to control network-wide broadcasts of RREQ packets. By using time to live (TTL) value, the source node starts searching the destination in this technique. The TTL value will be incremented by an increment value if there is no reply within the discovery period. This process continues until threshold value is reached.

On forwarding the RREQ the intermediate node records the address of the neighbor from which first packet of the broadcast is received thus establishing a reverse path. The route reply (RREP) towards the source node is sent when the RREQ is received by a node that is either the destination node or an intermediate node with a fresh enough route to the destination. When the RREP is routed back along the reverse path, the intermediate nodes along this path set up a forward path entry to the destination in its routing table. A route from source to the destination established when the RREP reaches the source node.

### 4.1.2 Route Maintenance

A route established between source and destination pair is maintained till it is required by the source. Route discovery is reinitiated to establish a new route to destination when the source node moves during an active session. When the destination node or the intermediate node moves, the routing entry is removed by the node upstream, and route error (RRER) message is sent to the affected active upstream neighbors. To reach the source node, these nodes broadcast the RRER to their originator nodes and so on. By sending out a new RREQ message, the affected source node either stop sending data or reinitiate route discovery for that destination.

## 4.2 Combined Cost Value

In the cross layer based routing, we estimate a combined cost value of our routing metrics for routing. The combined cost (C) value is given as,

$$C = \frac{D}{P \times LQ}$$

Where D is the end-to-end delay, P is the power and LQ is the link quality.

To compute *C,* a node conveys the information of the metrics in the RREQ packets along with the aggregate *C* value. Each node before forwarding a RREQ, first extracts this information. It then computes the new *C* value for each wireless interface operating channel. Finally, it updates the aggregate *C* and the information of the metrics in the RREQ packet.

All nodes maintain a minimum aggregate *C* (Cmin) value along with each routing entry in the routing table. An intermediate node sets the *C*min to the value received in the first RREQ. All subsequent copies of the RREQ are forwarded only if their aggregate *C* value is lower than the *C*min. If the value is lower, the current *C*min is replaced by the lower one. This ensures that the RREQ with the maximum channel diversity and least congestion is always forwarded and used for route creation.
In worst case scenarios, it is possible that multiple copies of the same RREQ with decreasing aggregate *C* values are received by a node. Thus we will have additional RREQs propagating in the network. However, the optimal RREQ with least aggregate *C* is generally received earlier than those with higher aggregate *C* values, since the optimal RREQ go across paths with maximum channel diversity and least loaded interface queues.

## V. SIMULATION RESULTS

### 5.1 Simulation Model and Parameters

To simulate the proposed scheme, network simulator (NS2) is used. The proposed scheme has been implemented over IEEE 802.16 MAC protocol. In the simulation, clients (SS) and the base station (BS) are deployed in a 1000 meter x 1000 meter region for 100 seconds simulation time. All nodes have the same transmission range of 250 meters. In the simulation, CBR traffic is used.
The simulation settings and parameters are summarized in table 1.

**Table 1:** Simulation Settings

| | |
|---|---|
| Area Size | 1000 X 1000 |
| Mac | 802.16 |
| Nodes | 5,10,15,20 and 25 |
| No. of Flows | 1,2,3 and 4 |
| Radio Range | 250m |
| Simulation Time | 100 sec |
| Traffic Source | CBR |
| Physical Layer | OFDM |
| Packet Size | 1500 bytes |
| Frame Duration | 0.005 |

### 5.2 Performance Metrics

We compare our proposed CLBQR scheme with the CLQS scheme [7]. We mainly evaluate the performance according to the following metrics:
**Packet Delivery Ratio:** It is the ratio of the number of packets received successfully and the total number of packets sent.
**Energy Consumption:** It is the average energy consumption of all nodes in sending, receiving and forward operations
**Average end-to-end delay:** The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

### 5.3 Results

**Based on Flows**

In the second experiment, we vary the number of flows from clients as 1, 2, 3 and 4.
Figure 2 gives the packet delivery ratio when the number of sources is increased. Since reliability is achieved using the dispersion technique, CLBQR achieves good delivery ratio, compared CLQS.
Figure 3 shows the results of energy consumption when the number of sources is increased. From the results, we can see that CLBQR technique has less energy consumption when compared with CLQS.

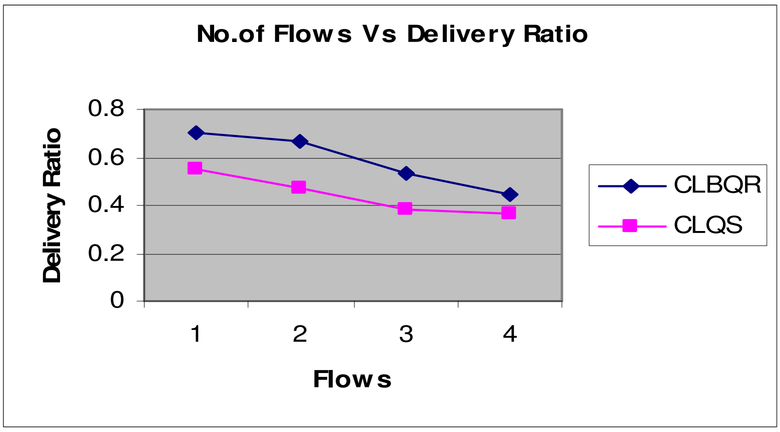


**Fig: 2** Sources Vs Delivery Ratio

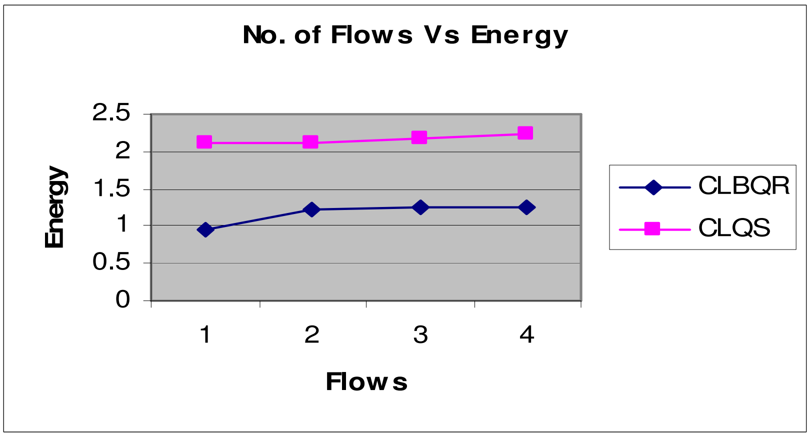


**Fig: 3** Sources Vs Energy

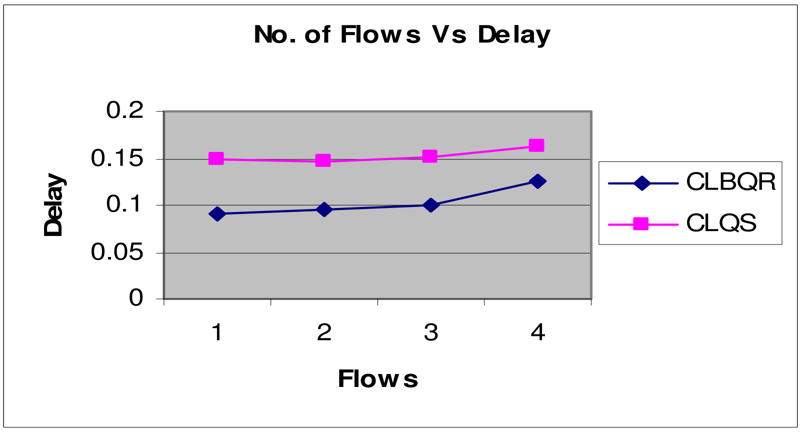


**Fig: 4** Sources Vs Delay

Figure 4, we can see that the average end-to-end delay of the proposed CLBQR technique is less when compared with CLQS

## VI. CONCLUSION

In this paper, we have developed a Cross-Layer Based QoS Routing (CLBQR) Protocol for 802.16 WiMAX Networks. In our protocol, the cross layer routing is based the routing metrics which includes power, link quality and end-to-end delay. In order to realize QoS provisioning with efficient resource allocation an optimal power allocation is required. We use the EETT (Exclusive Expected Transmission Time) metric to estimate the link quality where EETT is a routing metric which is used to give a better evaluation of a multi-channel path. The end-to-end delay of a packet is the time it takes to travel from the source node to the destination node including intermediate links' transmission delays and nodes' queuing delays. For the estimation of queuing delay, we use the average queuing delay at each node. Our protocol is the derivative of the AODV routing protocol which is the variant of classical distance vector routing algorithm. Then the routing is performed based on the routing metrics by estimating a combined cost value. By simulation results, we have shown that our proposed protocol achieves higher packet delivery ratio with reduced energy consumption and delay.

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