QoS Provisioning in WMNs: Challenges and a Comparative Study of Efficient Methodologies

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ABSTRACT
Wireless Mesh networks have made it possible to have seamless connectivity in between the community users. WMN is a low cost network supporting multihop communication through a backbone like structure. But, to provide services like neighborhood and community network, broadband home network, building enterprise network QoS provisioning is very much essential. In this paper, we presented a comparative study of the three efficient QoS provisioning methodologies while presenting the requirement and challenges for QoS provisioning for Wireless Mesh Networks. Moreover, this paper also includes the key advantages of deploying Wireless Mesh Networks.

Keywords
QoS, admission control, WMN, multihop, bandwidth.

1. INTRODUCTION
Over last few years, Wireless Mesh Networks [1] have emerged as a popular and promising network through its seamless broadband service. Moreover, Wireless Mesh Networks are self managing and self healing in nature. WMNs enabled routing of data packets over multiple wireless hops. WMNs are self healing in the sense that source node or intermediate nodes can send their data through optional routes (if available) if there is a link failure.

Wireless Mesh Networks aim towards constructing a multihop wireless hierarchy to establish connectivity between isolated LANs. Furthermore, WMNs have made it possible to provide interconnection between the nodes which are not within the transmission range of the Access points. As a result of the existing static infrastructure in some part, WMNs can consider link quality issues in routing of data packets.

2. KEY ADVANTAGES OF WMN
Before the advent of Wireless Mesh Networks [2] it was quite impossible to even dream about seamless connectivity. WMNs provide the flexibility of effectively, easily and economically connect the large scale LANs and wireless nodes. The key advantages provided by WMNs can be listed in the following manner:

2.1 More economical
Wireless Mesh Networks engages only some of its infrastructure to be static i.e. only this part need wires and less wires means less expensive. Again, No centralized controller is needed to deploy Wireless Mesh Networks.

2.2 WMNs are adaptable and expandable
Wireless Mesh Networks are expandable and scalable in the sense that mesh routers can be easily added or removed from the existing network. Moreover, WMNs are pretty much effective in the areas where infrastructure is unavailable such as outdoor environments.

2.3 Support for high demand
Critical information like public safety and emergency response demand for low delay, guaranteed services and also demand for wireless connectivity covering large areas, highly mobile and high quality video surveillance which can be provided only through Wireless Mesh Networks.

2.4 Easy and rapid installation
Mesh routers can be easily and rapidly deployed as no infrastructure and wiring is required. This key advantage also makes Wireless Mesh Networks scalable.

2.5 Less power consumption
As wireless Mesh Networks support multihop flows the transmission range of a mesh node need not be covering a large area. As a result power consumption is very less in Wireless Mesh Networks.

2.6 Self healing and self organizing
Wireless Mesh Networks are more resilient as compared to traditional wireless networks due to the absence of communication losses because of node failure. Moreover, WMNs are also deployable in high mobile and frequently changing environments.

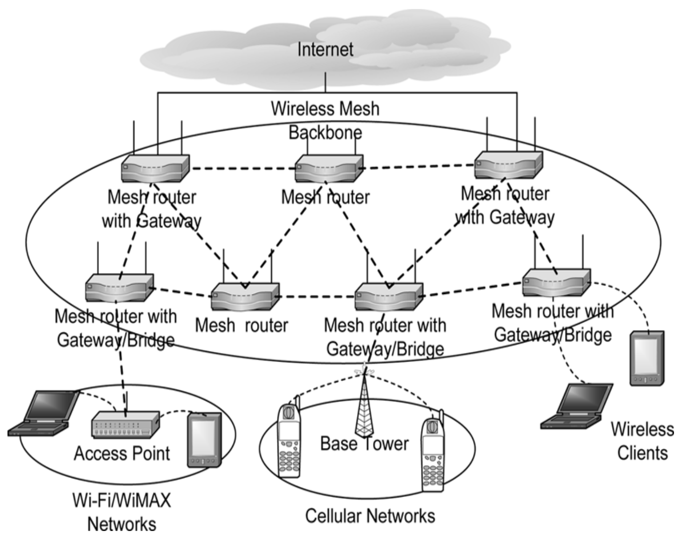

Fig 1: Typical Wireless Mesh Network

3. QoS REQUIREMENT AND CHALLENGES

3.1 Requirement for QoS provisioning

Basically, QoS provisioning [3] can be viewed as satisfying a set of parameters (such as jitter, latency and packet loss ratio) according to RFC 2386.

3.1.1 Emergence of traffic sensitive application

Real-time applications and multimedia applications require bandwidth guaranteed paths to drive their data flows as no excessive delay can be tolerated.

3.1.2 Large number of users

Recently, with the increasing popularity of Wireless Mesh Networks, numbers of community users have been increasing significantly. Therefore, to provide equally likely services QoS provisioning is the first and foremost need.

3.1.3 Categorization of data flow

Contention based MAC access methods such as CSMA/CA treat every data frame equally without considering their application types. Hence, node level and MAC layer QoS provisioning must be provided to enable distinction in between different types of traffic.

3.1.4 To account unreliability of communication medium

As the wireless medium is shared in nature, it is more prone to errors especially in case of multihop communications. Issues like interference, multipath fading often significantly influence a transmission. Though introduction of multiple channels reduce the intraflow interference to a good extent but impact of interflow interference and self interference cannot be ignored.

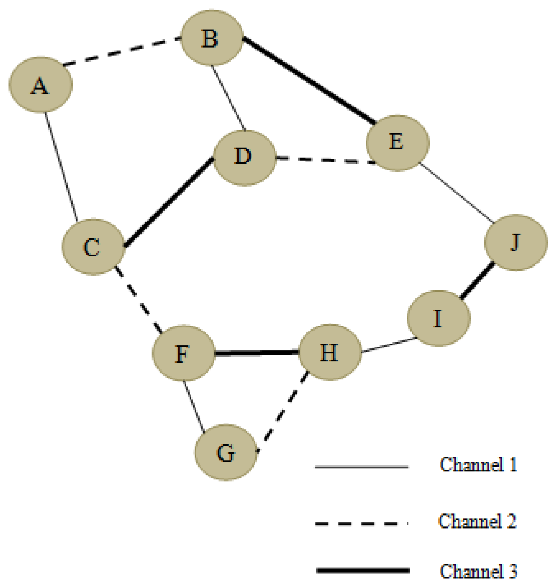

Fig 2: Typical channel assignment on a multichannel mesh

3.1.5 Solving the unpredictability of channel access delay

In the absence of centralized controller, media access control is provided through a distributed algorithm. As a result, a bound on channel access delay is to be ensured through proper QoS provisioning.

3.2 Challenges in QoS provisioning

QoS provisioning in multihop wireless network [4] is far more tough ask as compared to wired networks. Some of the major problems are listed below:

3.2.1 Capacity related issues

Wireless channels are far more scarce and costly. Moreover, QoS provisioning can be provided only by the bandwidth guaranteed paths. Hence, unavailability of bandwidth is a major concern in QoS provisioning. Though, multiradio environment has solved this issue to a great extent but still this is a critical issue.

3.2.2 High mobility and frequent topology change

Wireless nodes are generally mobile in nature and the topology changes very frequently. As a result the routing information becomes stale and frequent route updating is necessary.

3.2.3 Limited battery life

As wireless nodes run on a limited power the catastrophic failures like battery exhaustion randomly occurs. As a result intermediate nodes start misbehaving, while route table information become stale.

3.2.4 Dependency on distributed strategy

Wireless Mesh Networks do not employ any centralized controller rather a distributed algorithm provides media access control. Hence, QoS provisioning with a distributed algorithm is a tedious ask.

3.2.5 Heterogeneity of Network

A large level of heterogeneity is present in Wireless Mesh Network especially in between mesh client and mesh routers. Mesh routers atre mostly static in nature and equipped with multiple NICs where a typical mesh client is highly mobile and equipped with single radio.

3.2.6 Bandwidth estimation problem

Wireless channel bandwidth is influenced by multiple issues like interference, multipath fading, traffic load and nodes' communication range. Therefore, accurate estimation of wireless channel bandwidth is difficult.

3.2.7 Link quality measurement issues

The control packets used for computing the link quality such as packet loss ratio, bandwidth measurement are smaller in size as compared to average data packets. Hence the probing information becomes quite ineffective.

3.2.8 Differentiation in QoS services
Different types of services require different types of QoS requirement. Hence to develop a single standard model to provide all set of QoS requirement is very much challenging.

4. QOS ROUTING METHODOLIGIES
QoS routing [5] in Wireless Mesh Networks is recently being investigated exhaustively because of its different requirements such as guaranteed delivery. Moreover, availability of static infrastructure in WMNs provides the flexibility of investigating the set of QoS requirements. In this section, we present a brief study of the main QoS provisioning methodologies.

4.1 QUORUM protocol
The route discovery phase of the Quality Of service in wireless Mesh networks (QUORUM) [6] is carried out in a reactive manner and the QoS provisioning is solely based on reservation.

4.1.1 Robustness in selection of links
Robustness of a link is computed through counting the hello message frequency that are received from the neighborhood during a given period of time.

4.1.2 Restriction on flooding
QUORUM reduces flooding of control information by limiting the number of nodes which can broadcast. If only a single mesh router covers the services of the source and the destination node then flooding is limited only to hat group which are under the services of that mesh router. On the other hand if source and destination nodes are covered by different mesh routers then flooding is limited only to the groups of those two mesh routers which serve the source and destination while all the mesh routers also receive the control information.

4.1.3 Misbehaving node management
QUORUM assumes that node misbehaving can occur if and only if intermediate nodes do not broadcast the control traffic received from the other nodes while continues listening to its neighbors. In order to encounter his issue QUORUM sets a threshold based on the link quality such that a node forwards a data packet only if its link quality is greater than the specified threshold.

4.1.4 Admission Control mechanism
Admission control is ensured in the reactive route discovery phase where it is decided that whether a new incoming flow can be admitted or not. Moreover, a Flow Table entry is listed corresponding to all the admitted flows which are accepted.

4.1.5 Strict QoS recovery
To detect flow error QUORUM uses flow table entries such that any incoming data packet having no corresponding flow Table entry is treated as reservation time out. Moreover, QUORUM also maintains a maximum delay threshold to guarantee maximum delay limit.

4.1.6 Delay estimation
The basic end-to-end delay estimation is based on DUMMY-RREP packets which are carried out in the route discovery phase. Again, the DUMMY data packets which are used for the purpose of estimation are equal in size to the actual data packets to analyze real traffic environments.

4.2 WMR Protocol
In the case of route discovery Wireless Mesh Routing (WMR) [7] also uses reactive approach similar to that in QUORUM protocol.

4.2.1 Route Table updating
As in the QUORUM protocol Wireless Mesh Routing (WMR) is also dependent on the periodic HELLO messages to grab the topology changes and updates the routing information. All the mesh nodes maintain a hop-count metric which is the hop distance from the node's corresponding mesh router.

4.2.2 Proactive routing
Table driven approach or proactive approach is used in WMR to explore the routes. Corresponding bandwidth and delay information is embedded in the HELLO messages itself. To limit the number of flooding TTL field is used.

4.2.3 Admission Control
A node estimates whether the basic QoS requirements can be satisfied upon receiving a route request and updates the route information as explored.

4.2.4 Reservation or registration of routes
When a source node receives a route reply then it again checks for the QoS constraints whether the new incoming low can be admitted further. The status of the Flow Table entry is then updated as registered. The data packets from the incoming current flow can be accepted after updating the status as registered.

4.2.5 Bandwidth computation
Wireless Mesh Routing (WMR) employs an estimation method to compute the available bandwidth at nodes by estimating its current bandwidth consumption and its neighboring nodes.

4.2.6 Violation detection and recovery of QoS
If the destination node detects a reservation time-out and further starts a route discovery towards the source then it is marked as a QoS violation. In order to solve such issues the destination node initiates a route discovery but this kind of solutions often lead to other problems like finding of unidirectional routes.

4.3 OLSR with MAvB metric
The Optimized Link State Routing [8] protocol is an optimized version of the traditional Link State Routing which provides the flexibility to include link quality extensions. We had derived a bandwidth based metric Maximum Available Bandwidth (MAvB) [9] which estimates the necessary available bandwidth estimation for establishing QoS provisions while routing in Wireless Mesh Networks with the OLSR protocol.

4.3.1 Flooding control
Flooding of control information is restricted in the OLSR protocol (IEEE 802.11s). The MutiPoint Relay (MPR) node concept is used according to which broadcasting of control messages is done by only the MPR nodes .For each and every MPR node there is a corresponding MPR selector set.

4.3.2 Interference aware routing

OLSR protocol with MAvB metric encounters the interference issues by computing the consumption of bandwidth due to interflow, intraflow and self interference.

4.3.3 Available node bandwidth estimation

The traditional OLSR protocol does not provide any methodology t estimate the node-to-node available bandwidth. But, in our previous work we had shown an effective methodology to compute the available bandwidth of a mesh node by computing the bandwidth consumption due to interference issues accurately.

4.3.4 Admission control

Admission control is provided through the bandwidth estimation methodology. The methodology computes the bandwidth that is required to drive the multihop flow.

4.3.5 Effective topology discovery

OLSR protocol uses Topology Control messages to update the routing information. Only the MPR nodes broadcast TC (Topology Control) messages in order to grab the frequent topology changes.

5. Comparative Discussions

QoS provisioning in Wireless Networks also uses some key concepts of the wired networks. However, as wireless networks suffer from extra difficulties such as interference and multipath fading they also need some extra techniques to tackle those issues. This section compares the above three methodologies in terms of different key issues:

5.1.1 Limiting flooding of control messages

QUORUM limits the flooding messages by limiting the broadcasting privileges to the mesh routers which covers the source and destination. Whereas, OLSR limits flooding by limiting the broadcasting authority only to the MPR nodes selected by the mesh nodes in the network.

5.1.2 Admission control

QUORUM and WMR uses bandwidth based approach to control incoming flows. However, these two methodologies do not consider the interference issues explicitly. OLSR primarily does not consider any admission control mechanism. But, when OLSR is used with MAvB metric, a bandwidth based admission control can be provided.

5.1.3 Interference awareness

QUORUM and WMR protocols do not provide any methodology to estimate the impact of interference which is pretty much necessary in case of Wireless Mesh Networks. In our previous work we have provided a mathematical model for accurate interference estimation. All the three types of interference that is interflow interference, intraflow interference and self interference are explicitly considered.

5.1.4 Awareness towards dynamic topology

QUORUM and WMR requires node level awareness to grab the characteristics of the mesh network. Whereas, OLSR uses Topology Control messages to update the topological information.

5.1.5 Misbehaving node management

QUORUM ensures the detection of misbehaving nodes which do not broadcast the HELLO messages forwarded by other nodes. But, WMR does not provide any such mechanism of misbehaving node detection. OLSR primarily does not provide misbehaving detection but inclusion of some extensions an provide that facility too.

5.1.6 Protection of reservation information

IEEE 802.11b/g/s provides fixed transmission slots which are useful in calculation of channel business time. OLSR protocol with MAvB metric uses this information in calculation of bandwidth consumption.

6. CONCLUSION

The key advantages of Wireless Mesh Network over traditional wireless network are discussed in this paper. We also presented the essentiality of embedding QoS provisioning techniques. We presented a comparative study of three efficient methodologies providing QoS provisions. It is clear from the discussion that OLSR protocol with MAvB metric outperforms the other three methodologies in case of ensuring QoS provisions.

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