A Survey on QoS in Wireless Mesh Network

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***Abstract*— The wireless mesh network is a new emerging technology that will change the world of industrial networks connectivity to more efficient and profitable. Mesh networks consist of static wireless nodes and mobile customer; have emerged as a key technology for new generation networks. The QoS is designed to promote and support multimedia applications (audio and video), real time (ToIP, VoIP). However guarantee of QoS on wireless networks is a difficult problem by comparison at its deployment in a wired IP network. The reason is the random mobility of nodes, the nature of wireless channel (interference), the multi-hop communication and the lack of a central coordinating authority. Wireless Mesh Networks (WMNs) are commonly considered the most suitable architecture because of their versatility that allows flexible configurations. Different studies have proposed number of protocols in different layers of model TCP/IP to enhance transmission of data and its QoS. This paper mainly focuses on classification layer of the largest existing approaches dedicated to QoS. It is also discussing the most interesting works on QoS in WMNs networks.**

Keywords-WMN; QoS; TCP/IP; Routing protocols.

I. INTRODUCTION

The Internet in the near future will be everywhere and offer broadband today, that we have never experimented. Networks invade all sectors with individuals and organizations always interconnected private networks and connected to the internet.

These networks aim to provide a wide range of beneficial social functions: individual medical monitoring in urban and rural make up and support business projects effectively. The WMN is a promising candidate for the implementation of such connectivity, also known for its ease of deployment.

A group IEEE 802.11s was created in January 2004 [1] to provide benefits and features of the mesh network architectures and IEEE 802.11 protocols. More specifically, to define the necessary amendments at the MAC and physical layers to create a wireless distribution system based on IEEE 802.11 technology.

WMN self-organizing and self-configure increases the coverage of wireless LAN standard (802.11n) to the wireless mesh MAN (802.11s) without significant additional infrastructure deployment. It also offers a good platform for promoting social partnerships in urban and rural areas.

In the non-meshed WLANs, stations must associate with an access point (AP) to access the network, and these stations depend on this access point with which they have come together to communicate. In a mesh APs can communicate with each other directly without going through an external network. [1]

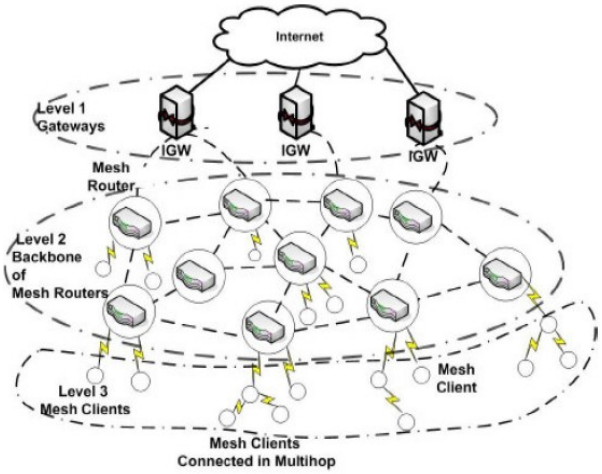

Figure 1. WMN architecture

An example of mesh networks is illustrated in Figure 1. In fact, a mesh network is divided into three parts:

- The first level is generally distinguished gateway nodes for wireless mesh nodes passed to external networks such as Internet, GSM, WiMax, etc
- The 2nd level is the mesh nodes (wireless AP) that are usually fixed to create the skeleton of 802.11s wireless network and serve the 3rd level.
- The 3rd level is composed of Mesh customers; these customers are often mobile and use services via the 802.11s.

The remainder of the paper is organised as follows. First, we discuss about WMN uses in different cases, second is an introduction to our analyzes and comparisons in Section 3. A network layer approaches is explained in Section 4. A link layer approaches is presented in Section 5. At last, a physical layer approach is elaborate in section 6, with a global concluding and remarks in Section 7.

II. THE IEEE 802.11S USES

The wireless mesh network defines four possible deployments: residential deploying for the digital home, deployment for a company as WLAN, deployment in public places to allow access to the internet and finally as temporary wireless network infrastructure disaster.

In the residential case, the mesh network, also called the digital home, will create low cost and ease of deployment with an excellent wireless coverage in all

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floors of the house. The main motivation behind the introduction of mesh networks to provide connectivity in the company is to use a wireless technology performance, reliable, inexpensive and easy to deploy. This allows companies to control costs associated with network installation and reduce the time required for deployment but also guaranteeing mobility for employees.

III. APPROACHES FOR QOS IN WIRELESS MESH NETWORK

Different approaches have been proposed by the state of the art spread over the different layers of the TCP / IP, we will summarize the most interesting in the following section.

IV. A NETWORK LAYER APPROACHES

As WMNs become an increasingly popular replacement technology for last-mile connectivity to the home networking, community and neighborhood networking, it is imperative to design an efficient resource management system for these networks. Routing is one of the most challenging issues in resource management for supporting real-time applications with stringent QoS requirements.

In general, there are two main kind of routing protocols for multi-hop wireless networks: (i) topology-based protocols which need topological information to set up a path between the nodes, (ii) position-based protocols which require some geographical information for the route discovery process. Among the topology-based routing protocols considered here, two distinct categories can be defined:

Proactive which maintain the information about the routes to every node all the time by sending periodic updates even if the nodes do not communicate with each other, including DSDV (Destination-Sequenced-Distance Vector),OLSR (Optimized Link State Routing) and MPR (Mesh Networking Routing Protocol)

Reactive called also 'on-demand' for which the paths are computed and maintained only when needed, including AODV (Ad-hoc On-demand Distance Vector), and DSR (Dynamic Source Routing) [2].

DSDV ([3], [4], [5]). It is a modification of Bellman-Ford algorithm implemented in RIP (Routing Information Protocol) adapted for self-configuring networks. Every node maintains its own routing table with the information about network topology and the cost of the links between the nodes.

OLSR ([6], [4], [5]). It uses shortest-path algorithm having the access to the routing information whenever it is needed (storing and updating periodically). The optimization idea is based on specific neighborhood detection and Multipoint Relays (MPR-s) selection concept.

MRP [9]. In this protocol each client is chosen a gateway to connect to the internet. If the gateway fails or the node moves, the node will choose a different gateway. All the traffic is assumed to flow through the gateway to the internet. This protocol is mainly available in three versions. One of the versions is MRP on-demand.

AODV ([7], [4], [5]). It uses Route Request/ Route Reply (RREQ/RREP) mechanism for route discovery and destination sequence numbers for each route entry like DSDV. This helps detecting outdated routing. Moreover, it keeps track of the next hop instead of the entire route.

DSR ([8], [4], [5]). Similarly to AODV, it is based on RREQ/RREP packets. However, RREQ gathers the addresses of the 'visited' nodes and maintains information about the whole path from the source to the destination node, not just the next hop. Moreover, the information is stored by every node in a route cache instead of the routing table.

Several studies have compared the routing protocols used in most networks Mesh, to find, expand and improve those who gave the best results; the most recent are listed below.

A. Analysis of Routing Protocol Performance in Wireless Mesh Networks

This work [2] is divided into two parts: the first part, the compared protocols are: AODV, DSR, DSDV and OLSR, using a fixed topology and other mobile on wireless mesh network with NS -2. The results show that the protocol AODV is the best in terms of delay, throughput and that the DSR is the worst among the four protocols mentioned.

Furthermore, the authors introduced TCP and UDP in the scenarios of the first part, to assess the degree of impact of the transport layer at the network layer. The results confirm that UDP is more interesting than TCP in terms of QoS management.

There is no ideal and the best routing recommendation for WMN. From the protocols studied in this paper, OLSR and AODV should be considered as the ideas worth considering. However, scalability is one of the crucial problems also in this case. One of the solutions is to propose a new routing metric for the existing protocols, use hybrid routing techniques or/and multiple radios and interfaces in order to improve performance of the network and provide better capacity of the network

B. R-AODV Rate Aware Routing Protocol for WMN

After our previous analysis and existing literature, the routing protocol AODV is most advantageous to ensure QoS, and naturally, lot of works was directed towards the extension of AODV, to improve its performances. It is the aim of the paper [10]. Rate aware routing protocol based on AODV (R-AODV) [9] uses minimum network layer transmission time as a performance metric. Nodes will select higher data rate link using R-AODV.

The simulation result indicates that R-AODV can improve the network throughput and decrease network delay.

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C. Optimization of routing algorithm in WMN

For specific application like, emergency or search and rescue operations in case of natural disaster, policing and fire fighting military applications such as on the battle field, meeting rooms, sports stadium etc, almost all routing protocols in one way or other, try to converge into shortest path routing. One of the advantages of using shortest path routing is that it is good for overall energy efficiency because energy needed to transmit a packet is directly proportional to path length or number of hops. But the shortest path routing is restricted to use the same set of hops to route the data packets, thus causing some of the heavily loaded nodes and thus causing some of the nodes to die earlier resulting into holes in the network or even worst into partitioning of the network. Thus the need for load balanced routing emerges.

Authors in [11] formulate the problem of routing as a network optimization problem, and present a general LP (linear programming) formulation for modeling the problem. The authors propose the optimized algorithm for known traffic demand and then explain the performance ratio for this. The routing algorithms derived from these formulations usually claim analytical properties such as optimal resource utilization and throughput fairness. The simulation results demonstrate that their statistical problem formulation could effectively incorporate the traffic demand uncertainty in routing optimization, and its algorithm outperforms the algorithm which only considers the static traffic demand. To achieve this objective the problem for congestion has been designed.

D. A Throughput Optimizing Routing Protocol for Wireless Mesh Networks

The goal of the proposed routing protocol [12] is to establish a route from the source to the destination that allows traffic flow within a guaranteed end-to-end latency using the minimum control overhead. The protocol is based on a reliable estimation of wireless link quality and the available bandwidth on a routing path. It also minimizes control overhead by effectively controlling broadcast messages in the network. The QoS-awareness in the protocol is achieved by a robust estimation of the available bandwidth of the wireless channel and a proactive discovery of the routing path by an accurate estimation of the wireless link quality. In addition, the protocol uses the multi-point relay (MPR) nodes to minimize the overhead due to flooding.

The key contributions of the paper are as follows: (i) it exploits the benefits of using MPRs and circular routing to increase the network throughput by reducing the control overhead. (ii) It computes a link quality estimator and utilizes it in route selection. (iii) It provides framework for reliable estimation of available bandwidth in a routing path so that flow admission with guaranteed QoS satisfaction can be made. It also ensures that the number of retransmission required is minimized.

E. Routing Packets into Wireless Mesh Networks

On the forward path, from mesh nodes to Internet nodes, for all mesh nodes only route information for one destination, the gateways, needs to be maintained. However, on the backward path from the Internet to mesh nodes, an individual route for every mesh node is required.

In [13], the authors investigate protocols for backward path routing in wireless mesh networks. Using simulation experiments with realistic mobility patterns of pedestrians and cars in cities, they compare three protocols, each of which represents a routing protocol family: (i) AODV with an extension for mesh networks, a reactive routing protocol, (ii) FBR, a proactive routing protocol, and (iii) GSR, a source routing protocol. Their results indicate that FBR has the highest packet delivery ratio but is not scalable to the network size. The extended AODV seems to be neither scalable nor does it achieve a high packet delivery ratio. A good compromise is provided by GSR, which is the most scalable.

F. Backup Routing for Multimedia Transmissions over Mesh Networks

Liu et al. [14] proposed an available bandwidth estimation algorithm plus a QoS backup route mechanism to accommodate multimedia traffic flows in mobile wireless mesh networks. Moreover, to validate the correctness of our proposed algorithm, the authors have implemented the algorithm on the campus wireless mesh network testbed. Their implementation and experiments show that their mechanisms can improve the network stability, throughput, and delivery ratio effectively, while decreasing the number of route failure. They implement their proposed algorithms on the testbed through an improved DSR protocol. Their implementation and experiments show that the mechanisms can effectively improve the network stability, throughput, delivery ratio, while decreasing the route invalidation ratio, and can guarantee the fluent transmission of multimedia streams.

In order to support multimedia transmission with QoS requirements, they improve the wireless routing protocol on the testbed with a dynamic ACK mechanism, which is used to balance the throughput and the quality of transmission. Additionally, authors introduce a dynamic mechanism to change the

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multimedia coding rate dynamically at the source node according to the available bandwidth. Moreover, they also made improvement on the admission control protocol to facilitate an experiment.

G. *Efficient Routing Anomaly Detection in Wireless Mesh Networks*

The throughput of a WMN may be severely degraded due to presence of some selfish routers that avoid forwarding packets for other nodes even as they send their own traffic through the network. Jaydip Sen. [15] presents an algorithm for detection of selfish nodes in a WMN.

It uses statistical theory of inference for reliable clustering of the nodes and is based on local observations by the nodes. Simulation results show that the algorithm has a high detection rate while having a low rate of false positive

H. *Algorithm for Congestion Control in Wireless Mesh Network*

Congestion control is an important research area in wireless mesh network (WMN). In order to solve congestion control in WMN, a random routing algorithm based on path weights (WA) is presented. The algorithm adopts multi-gateway wireless mesh network routing protocol to solve the congestion problem of single gateway.

And any cast service was used to ensure the successful rate of service requests. Simulation results show that WA is the better algorithm as it has less average wait time and the successful rate of service requests. The algorithm can effectively solve congestion problem, and make the network stable and efficient.

I. *A new vision of routing protocol*

The mesh network, as is a special case of Ad-hoc networks and MANET networks. These include a new vision of routing protocols based clusters, whose principle is very simple: divide the whole network into several parts, each party will elect a central node, responsible for coordination of routing information between other adjacent nodes, that node is named CH (Cluster Head), other nodes called its members.

Communication in this type of network is simple, any member wishing to transmit, do it through its CH. The latter has a routing table, if the destination is internal (in the same group), then the delivery will be direct, if not the CH sends queries to neighbors to find the right path.

Very recent works have focused on this type of MANET routing. Mukesh Kumar [16] compared a routing protocol named CBRP (Cluster Based Routing Protocol) which gave results much interest as the basic protocols in terms of QoS (delay, throughput) and a good transition to across the MANET.

J. *Conclusion*

The first assertion that we can do, is that, according to the comparative studies results, done to determine what is the best choice between the existing routing algorithms in the state of the art, AODV and OLSR are the best choice by report to others, in terms of QOS.
The second assertion is that several trends have emerged, as follows:

- Extending the traditional routing algorithms such as AODV, DSR, OLSR, to improve their performances.
- Changing values of the metric, like hybrid or dynamic metric, as bandwidth of links, or end-to-end latency instead of number of hops, for example.
- Propose protocols completely different from those present in the802.11s standard
- Use of the clustering approach

V. A LINK LAYER APPROACHES

MAC protocol design is important in meeting QoS requirements since much of the latency experienced in a wireless network occurs in accessing the shared medium. In addition, MAC protocols must be interoperable with existing wireless networks operating on the same RF spectrum and fair toward all users.

A. *A Distributed QoS MAC Protocol for Wireless Mesh*

Abundant hidden node collisions and correlated channel access due to multi-hop flows degrade QoS in wireless mesh networks. QoS in nearby WLANs operating on a single channel is also affected. Mathilde Benveniste [17] propose using wider contention windows for backoff to lower the risk of repeated hidden-node collisions, a spatial extension of the TXOP concept called 'express forwarding' is an enhancement of the CSMA/CA protocol designed to reduce the latency experienced end-to-end by a multi-hop wireless mesh to clear multi-hop flows sooner, and a new mechanism called 'express retransmission' to reduce collisions on retransmission. Simulation results show the potential benefit of the proposed enhancements and impact on fairness.

B. *A Novel Spatial TDMA Scheduler for Concurrent Transmit Receive WMN*

A key approach to increasing network capacity is to equip wireless routers with smart antennas. These routers, therefore, are capable of focusing their transmission on specific neighbors whilst causing little interference to other nodes. This, however, assumes

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there is a link scheduling algorithm that activates links in a way that maximizes network capacity. To this end, Chin et al. [18] propose a novel link activation algorithm that maximally creates a bipartite graph, which is then used to derive the link activation schedule of each router.

Authors verified the proposed algorithm on various topologies with increasing node degrees as well as node numbers. From extensive simulation studies, authors find that their algorithm outperforms existing algorithms in terms of the number of links activated per slot, super frame length, computation time, route length and end-to-end delay.

C. *A Real time Video Stream Aggregation in WMN*

Navda et al. [19] design and evaluate Ganges, a wireless mesh network architecture that can efficiently transport real time video streams from multiple sources to a central monitoring station. Video quality suffers from deterioration in the presence of bursty network losses and due to packets missing their playback /deadline. Ganges spatially separates the paths to reduce inter-flow contention. It finds out a fair rate allocation for the different video sources.

The wireless routers in the mesh network implement several optimizations in order to reduce the end-to-end delay variation. Ganges improves the network capacity by a shortest path tree, and video picture quality by Central.

D. *On the Support of Multimedia Applications over 802.11s*

The contribution of this work [20] is twofold. First Riggio et al. propose a methodology for evaluating multimedia applications over real world WMN deployments.

Second, based on the defined methodology, they report the results of an extensive measurement campaign performed exploiting an IEEE 802.11-based WMN testbed deployed in a typical office environment. The focus of their research on three mainstream multimedia applications: VoIP, Video Conference, and Video Streaming. Two single-hop star-shaped network topologies (with symmetric and asymmetric links) and a multi-hop string topology have been exploited in order to provide a comprehensive evaluation of the testbed's performances.

E. *Enhancing Video Streaming in 802.11 Wireless Mesh Networks using Two-Layer Mechanism Solution*

Moleme et al. [21] proposes a two-layer mechanism for the transportation of real-time video. In this mechanism, rate adaptation is implemented in the data link layer for channel error control, link stability and reliability. In addition, the network layer routing protocol is optimized for congestion control and optimal route selection by using congestion information from the data link layer and link quality metric from the network layer.

The proposed scheme aims at ameliorating the performance of UDP in WMV video streaming applications by improving throughput, packet loss and latency, so the authors in this work try to improve a standard protocol (UDP) to improve the QoS, us you know as we know, affect the operation of a standard protocol is a risk, it may have secondary effects on the proposed solutions

F. *An STDMA-Based Framework for QoS Provisioning in Wireless Mesh Network*

The framework is based on STDMA scheduling at the MAC layer, which is periodically executed at the network manager to adapt to changes in traffic demand. While scheduling computation is centralized, admission control is performed locally at the wireless backbone nodes, thus reducing signaling.

Leoncini et al. [22] propose two bandwidth distribution and related admission control policies, which are at opposite ends of the network utilization/spatial fairness tradeoff.

G. *Conclusion*

The link layer is very important to provide QoS for Wireless Mesh Networks. Researchers are focused on specific areas as we have seen. A set of researches focus on mechanisms of allocating resources such as CSMA/CA or TDMA. Other studied queue management, by doing a control admission, and another approach is to use correcting codes.

VI. A PHYSICAL LAYER APPROACHES

The problems of the propagation of radio waves in a cluttered environment with lot of obstacles, are numerous and known. Works on these problems were progressed, but new solutions are regularly found and proposed, as we shall see below.

A. *A Study of End to End Video Robust Transmission Via WMN*

The Video Transmission over the multi-path fading wireless channel has to overcome the inherent vulnerability of compressed video to the channel errors. To effectively prevent the corruption of video stream and error propagation in spatial and temporal domain, proactive error controls are widely been deployed. A novel video transmission architecture [23] via WMNs is proposed to meet the error robust requirement of wireless video Transmission. This architecture address a

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strategy of jointing sources coding and channel coding based on H.264 video code standard [23]. By taking the time-varying wireless channel condition and video codec characteristics into account.

B. *Characterizing the End-to-End Throughput in WMN Using Multiple Directional Antennas*

In WMN backbone, the throughput is mainly limited by 2 factors: the ingress/egress congestion in gateway and link interference caused by simultaneous transmissions. Recent study found deploying multiple gateways in WMN is an efficient way to alleviate the ingress/egress bottleneck. Besides, utilizing multiple channels, multiple radio interfaces and directional antenna technology in WMN can greatly alleviate interference problem. In the paper, we propose a practical wireless mesh networks architecture using multi-channels, multi-radios and multiple directional antennas. The end-to-end throughput characters of the proposed WMN are studied based on a network model considering the directional antenna.

A STDMA based centralized link scheduling algorithm is used to ensure proper operation of the backbone transmission. Zhao et al. [24] provide necessary conditions to verify the feasibility of rate vectors in the networks, and use them to derive upper bounds of achievable end-to-end throughput. The approaches are illustrated by simulation examples. The results show that their scheduling algorithm has a better throughput performance compared with scheduling algorithm using greedy method

C. *Distributed Gateway Placement for Cost Minimization in Wireless Mesh Network*

XiaoHua et al. [25] study the problem of gateway placement for cost minimization (GPCM) in two-dimensional wireless mesh networks. They are given a set of mesh routers; assume they have identical transmission range r, represented by unit transmission disks around them.

A router may be selected as a gateway at certain placing cost. A router is served by a gateway if and only if the gateway is within its transmission range. The goal of this work is to select a set of mesh routers as gateways to serve the rest routers with minimum overall cost. This problem is NP-hard. According to the authors, no distributed algorithm with a constant approximation ratio has been given before. Their algorithms greatly improve the best approximation ratios.

D. *Gateways and Performance of WMN*

Gateway has fixed bandwidth to be shared by all the clients for communication. It causes reduction in per client throughput as the number of clients is increasing and thus may lead to overall performance degradation. Associating clients to gateway is a crucial point in deciding performance as is gateway placement, routing and scheduling at the gateway. Associating nodes to a single nearest gateway causes reduction in capacity of WMN and unfairness amongst the nodes. Clients can be associated to multiple gateways. WMN are dynamically self-organizing and self-healing and this imposes even more responsibility on gateways. Having multiple gateways in clustered WMN can improve performance significantly.

E. *conclusion*

The solutions studied in the physical layer, generally focused on:

- The use of smart antennas, directed by our needs, to a particular neighboring node
- Reduction of rate of errors due to transmission
- Use of several gateways instead of one, to balance the load across the network
- The use of novel encoding methods, use of MIMO and use of different frequency of transmission at the same time, by the mobile stations, improve de rate of transmission

VII. GLOBAL CONCLUSION

This paper summarize the challenges in QoS provisioning for Wireless Mesh Networks (WMNs). We reach at the obvious conclusion that if we want to optimize network resources WMN to ensure QOS, the most effective way is to combine the most effective solutions in the three layers together.

In terms of routing, we think the approach of clustering is the most interesting and in another paper, we present our proposal of clustering routing algorithm, with a presentation and discussion of several simulations.

Regarding the solutions of Link layer, changing the CSMA/CA protocol in IEEE 802.11 is not recommended. The link layer provides various solutions for improving the QoS as queue management, error control, etc so we recommend instead, the use of a control admission algorithm, in addition to existed mechanisms of QoS provided in the standard, thus we limit the non-interoperability with equipment already in use.

The use of MIMO (Multiple Input Multiple Output) is already used by AP to increase the speed

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significantly; also the use of smart antennas is a good option to limit interferences.

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