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Design of Quality of Service (QoS) Model for MANET

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***Abstract*— MANETs are easily deployed on a shared wireless channel for the development of wireless communication systems. They are expected to provide the requisite quality of service for the delivery of real time communications. This paper contributes a new four layer QoS Model for MANETs to ensure effective utilization of resources. The implementation of this model will enable researchers to ensure QoS in MANETs, with proper selection of alternative variables at each layer. Universal applicability of the model may require its further extension to improve performance, with addition of one or more variables at each layer**.

***Index Terms*— Mobile Ad Hoc Networks, Quality of Service, QoS Model.**

I. INTRODUCTION

We start with definition of 'Quality of Service (QoS)' and list problems faced by mobile ad hoc networks in QoS provisioning. In ITU-T Recommendation E. 800 [1] Quality of Service determines the degree of satisfaction of a user of the service. In simpler way, QoS can be defined as the ability of the network to provide different services to various types of network traffic. The goal of QoS is to attain a more deterministic network behavior for optimal resource utilization.

The factors [2] which have major impact on performance of QoS protocols are node mobility, network size, traffic sources, node transmission power and channel characteristics. Node mobility [3] is characterized by node speed, speed pattern and pause time. The number of constant bit rate (CBR) traffic source affects network load and performance [4] respectively. The ability of the nodes to control their transmission power may affect the performance of routing protocols [5-7]. Firstly, dynamic nature of MANET is responsible for unreliable wireless channel. Secondly, the radio waves suffer from several impairments making it difficult to ensure hard QoS commitments. Mobile ad hoc network nodes can be in any of states-receive, transmit, idle and sleep mode. They consume energy in all these modes, which leads to depletion of finite energy and minimizes network lifetime.

In this paper, we have evaluated proposed model for energy consumption of AODV, DSR and DYMO routing protocols under DURACELL AA and DURACELL MX-1500 Battery Models by varying simulation time between 10 to 60 minutes. Each ad hoc scenario comprising of eleven nodes is simulated for Constant Bit Rate traffic in QualNet 5.0 simulator. Node is considered dead when its energy value goes down to zero. QualNet simulator periodically checks the battery status through a timer interval and shuts off the radio when the reservoir capacity goes to zero.

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II. RELATED WORK

We have gone through a vast collection of literature and studied various QoS Models, Routing solutions and multicasting. Fig. 1 represents the summary of QoS solutions for mobile ad hoc networks.

A. Existing QoS Models

We are listing some already existing QoS Models. IntServ architecture (Integrated Services) [8] ensures hard QoS through per flow end-to-end guarantees but with lower scalability so it is inappropriate for MANETS whereas DiffServ architecture [9] ensures scalability by defining per-hop behaviors at network edge routers in Internet. Flexible QoS Model [10] defines three classes of nodes and allots them dynamic roles for hybrid provisioning and adaptive conditioning. INSIGNIA represents [11] in-band signaling through IP packets ensuring stateful approach based on resource reservation.

Stateless Wireless Ad hoc Networks (SWAN) [12] model lacks resource reservation and is unable to ensure hard QoS guarantees making it unfit for real time traffic. DS-SWAN (Differentiated Services – Stateless Wireless Ad Hoc Networks) [13] provides end-to-end QoS in ad hoc networks connected to a fixed IP network. The TORA routing protocol provides numerous paths to the signaling protocol, INORA model [14] check them for necessary 1 requirements. Two-Layer QoS [15] separates QoS metrics according to the layers and traffic into classes for low delay, high throughput and best effort without any resource reservation.

PYLON [16] is an Architectural Framework for Ad-Hoc QoS Interconnectivity with Access Domains. DIADALOS [17] research project took initiative to integrate ad-hoc networks with infrastructure networks. Three Cross Layer Design [18] avoid duplicity of efforts to solve the accessibility problem in ad hoc networks. Hybrid QoS Model for Mobile Ad-Hoc Networks [19] combines the per-flow granularity of INSIGNIA and the per-class granularity of DiffServ. Complete and Efficient QoS Model for MANETs (CEQMM)[20] combines the IntServ and DiffServ models for provisioning of QoS in MANETs and is not suitable for small battery constrained wireless devices.

A new cross layer framework for QoS multicast applications [21] in MANETs worked through service differentiation. A cross layer QoS model called CLIASM [22] for MANET makes use of shared database for layers. Cross-layer QoS Mapping (CLQM) [23] framework for MANETs works on application, network and data link layers. The inability of Integrated Mobile Ad hoc QoS framework (iMAQ) [24] to model complete architecture for QoS support in MANETs is due to high overhead and lack of resource reservation.

B. QoS Multicasting

This defines the nature of routing decision to be taken among all nodes either centrally or distributive. In central scheme, it is the responsibility of source to compute multicast tree/mesh topology and share it with other nodes. In distributed scheme, participation of all nodes in routing process (request-reply) is must.

Multiple QoS Constraints

Bandwidth, delay, probability of packet loss, jitter, life-time and link reliability are some of QoS metrics for Multicast protocols. For a particular routing solution, it may happen that QoS metrics and QoS constraints differ. Example- For fulfilling bandwidth requirement of an application, stability metric could be utilized for route selection.

Admission Control-

Admission control can be done at source, receiver or at intermediate node. When the decision lies with intermediate nodes, each node on path checks for availability of sufficient resources to meet QoS requirement for forwarding route request. When the receiver is entitled to make decisions, it simply compares the quality of probe packets with known QoS requirements. On satisfactory results, it accepts session; otherwise, session is rejected. Finally, receiver sends its decision to the source. For admission control, source builds a multicast tree and computes QoS satisfied paths to all destinations. This multicast structure is informed to all involved nodes.

Resource Reservation/Release-

Resources need to be reserved to achieve a certain limit of QoS requirements. Implicit resource reservation mechanism treats a system as black box. When a new source or receiver needs to be admitted, end-to-end probing is done to determine the acceptability of resulting QoS. In explicit resource reservation, resources are associated to a particular node or a multicast group.

Resource Estimation-

Routing protocols estimate resources like bandwidth, delay, buffer, power etc. End-to-end probing forms the basis for Indirect estimation. For estimating available bandwidth, nodes exchange the information regarding current bandwidth usage for current session. 'Medium listening' estimates available bandwidth by observing incoming and outgoing traffic for a node. The capacity is calculated as the difference between the raw rate and the total of rate of flows through the nodes.

Tree/Mesh maintenance

Soft state maintenance technique demands periodic refresh of tree/mesh by the source or receiver at regular time interval of few seconds. Every link break is automatically repaired at beginning of refresh interval. Hard state maintenance mechanism requires additional technique to handle link break and joining/leaving of nodes using "Hello" packet. In mesh structures, packets are sent through primary and alternative paths. Hence, they are more robust and do not require any additional support until both primary and alternative links break down. However, when receiver node leaves the multicast group, the associated resource must be released and corresponding routing table is updated.

QoS Preemption

The preemption techniques are of two types: implicit and explicit preemption. Periodic admission control and resource reservation result into implicit preemption. QoS violation may be detected and recovered through explicit reservation. Network metrics for constructing routing path form the basis for protocol classification. Mostly, the "hop-number" is used as a metric. Mobile applications demand use of appropriate QoS metrics for packet routing and forwarding. Metrics, such as bandwidth, delay, jitter, packet loss and cost are used for routing path construction.

C. QoS Routing Solutions

Limitations of mobile ad hoc networks make it quite difficult to provide QoS. Still many QoS aware routing protocols [25-29] are proposed. Ad hoc QoS on Demand Routing Protocol (AQOR) [27] uses flooding while [26] avoids congestion by traffic classification. [29] presents modification of OLSR protocol by adding delay and bandwidth metrics. Several protocols are proposed in the literature with a provision of QoS at the level of routing. Their objectives and aims differ based on their applications and strategies uses.

Bandwidth estimation based routing

A QoS aware routing protocol based on bandwidth estimation[30] is proposed for mobile ad hoc networks. The protocol incorporates an admission control scheme together with a feedback scheme to meet the QoS requirements of real-time applications. The QoS routing protocol is based on Ad hoc On-demand Distance Vector (AODV) routing. The protocol is based on the intuition that the end-to-end throughput of a route depends upon the minimum end-to-end residual bandwidth available along the route. Bandwidth Reservation in Ad hoc Wireless Networks (BRAWN) [31] is proposed for multi-rate networks. BRAWN provides a network layer solution i.e. no modification is required at lower layers. The scheme employed computes the available bandwidth at a node which is then used to accept or reject a flow.

Interference aware routing

In Interference Aware QoS Routing (IQRouting) [32], several paths are probed using flow packets in a distributed fashion for satisfying QoS. The paths that satisfy the QoS are known as candidate paths. The path that is best in terms of the QoS amongst all candidate paths is chosen by the destination node.

Backbone based QoS routing

Core-Extraction Distributed Ad hoc Routing (CEDAR) [33] satisfy bandwidth requirements of a flow from a given source to destination. The protocol consists of three steps namely core extraction, link-state propagation, and route computation. In the core extraction step, a group of nodes are elected to form the core of the network in a dynamic and distributed fashion by using an approximate algorithm for minimum dominating set. A core node is responsible for maintaining the local topology of the nodes in its domain and it also computes the routes for these nodes.

Position based QoS routing

Geographical Vehicular Grid (GVGrid) [34] for Vehicular Ad hoc Networks is an on-demand and a position based routing protocol that identifies a route from a source node (which is a fixed base station) to vehicles that lie in a destination region. An underlying assumption in GVGrid is that every vehicle possesses a digital map and knows its geographical position and the direction of its movement through a Geographical Positioning System.

Multipath QoS routing

A QoS routing protocol called Ticket Based Probing (TBP) [35] uses a ticket which permits an intermediate node to search exactly one path. The source sends probes towards the destination to search for a low cost path that satisfy the QoS constraint. Each probe is required to carry at least one ticket and a probe with more than one ticket is allowed to split at an intermediate node each searching a different downstream sub path

QoS routing with resource allocation

A framework for generalized QoS routing with resource allocation [36] combines routing with the allocation of the resources along the routes. It employs a dynamic programming algorithm that tries to find an optimal path between a given source and a destination and computes the amount of resources required at each intermediate node so as to satisfy the end-to-end QoS requirements along the path. The QoS parameters considered are end-to-end delay, jitter, reliability, and bandwidth.

Constraint based QoS routing

A framework for sufficient rate constraints for QoS flows in ad hoc networks [37] is a theoretical model that predicts the capacity of an arbitrary ad hoc network. The proposed model uses a concept of a specialized graph called a conflict graph. A conflict graph represents the interference relationships between different links of the network. Specifically, a link in the network graph is represented by a node in the conflict graph. There is a link between two nodes in the conflict graph if the corresponding two links in the network graph interfere with each other.

III. BACKGROUND

Depending on the application involved, the QoS constraints could be available bandwidth, end-to-end delay, delay variation (jitter), probability of packet loss, and so on. This kind of demand puts more pressure on the network and the routing protocol which are used to support the communications. Mobile ad hoc networks experience several challenges at different layers making QoS provisioning very difficult. At Physical Layer, bit rate fluctuations and unpredictable link failures are dominant issues. Data Link Layer issues like transmission errors, scheduling real-time traffic and collisions create problems. Unpredictable Network topology changes, routing protocol constraints, resource reservations at Network Layer make QoS assurance very difficult. Hence, the performance of mobile ad hoc network depends on underlying routing protocols. The mobility model, battery model , energy model and the topology, network configuration, subnet(s), network size and type of traffic govern the behavior of routing protocols. We briefly explain these components.

A. Mobility Model

Simulations emulate coordination between node placement model, terrain and mobility model. File based mobility model makes use of a file while nodes belonging to a group move together following Random Waypoint Model. In simulations, the initial positions of nodes are determined through node placement models. Some of these models are File, Grid, Group, Pedestrian, Random and Uniform. In QualNet mobility model, the Cartesian coordinate system is used for small areas where the curvature of earth can be ignored, and the spherical coordinate system is used for larger areas terrain where the curvature of earth cannot be ignored.

B. Battery Model

Battery model may foresee behavior of real life batteries under different circumstances for battery based systems. Service life estimator model estimates the total service life of battery i.e. the time it takes the battery charge to reach zero from the start of the simulation. Residual Life Battery model estimates the remaining service life of the battery at any time in the simulation. Linear Model estimates the remaining battery capacity on basis of the difference between the accumulated value and a pre-recorded full charge capacity. The state of charge of batteries is periodically checked and if the battery is out of charge, the node is shut down.

C. Routing Protocols

The existing protocols can be broadly classified into three groups based on their behavior- reactive protocols (on-demand), proactive protocols (table driven) and hybrid protocols. Proactive protocols continuously learn the topology of the network by exchanging topological information among the network nodes. Thus when there is a need for a route to a destination, such route information is available immediately. If the network activity is low, the information about actual topology might even not be used.

Reactive Protocols proceed the establishment of route(s) to the destination only when the need arises. They do not need periodic transmission of topological information of the network. We have used some well known reactive protocols like Ad hoc On-demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR) and Dynamic MANET On-demand (DYMO) in our simulation scenarios. An entirely reactive routing solution avoids the wastage of channel capacity and energy by not discovering routes and QoS state which are not currently needed. However, a discovery delay incur when an application requires a route to a destination.

The following main points are identified for QoS issues in a mobile ad hoc network which illustrate that QoS provisioning in MANET is a multi-facet problem: Traffic

Type, QoS Metrics, Battery Model, Mobility Model, Energy Model, Energy Consumption in Transmit, Receive and Idle Mode and Scenario configuration in Simulator**.** Their different combinations may improve or degrade the performance of routing protocols. Keeping these in mind, we have proposed QoS

IV. PROPOSED QOS MODEL

Our proposed model (Fig. 2) consists of four layers: Objective Layer, Criteria Layer, Configuration and Protocol Layer respectively. Among the existing approaches of MANET for routing, reactive ones avoid resource wastage whereas proactive ones flood the network with control packets. Therefore, in our proposed model we have taken three reactive routing protocols. This model could be further extended for other reactive protocols, battery models, mobility models and network configurations.

A. Hierarchy Structure

The objective of our QoS model is to optimize the performance of routing protocols by selecting best alternative from each layer based on QoS metrics under study.

Objective Layer:

The ***objective layer*** forms the top layer of the model. Here the objective is "optimized performance of mobile ad hoc routing protocol ."

Criteria Layer:

Second layer from top comprises of ***criteria layer***. The criteria list is briefly explained. ***End to end delay*** is treated as a decisive factor especially for time-sensitive systems. The optimum route should have the smallest delay. ***Jitter*** - Every packet of live video may reach the destination with different delays due to the factors such as congestion and collision, and the difference is measured by jitter. Hence, jitter is considered as a factor. ***Throughput*** - An ideal routing protocol allocates traffic evenly for a higher throughput. Hence, throughput is a valuable metric for network resource utilization. ***Energy Consumption*** - Under energy controlled operations, optimized energy usage may extend lifetime of mobile ad hoc networks. Many mobile devices are battery powered and lower energy consumption will prolong the lifetime of the node as well as the system.

Configuration Layer

MANETs prefer simulation modeling to model network-level details. The random waypoint mobility model is the most commonly used technique to define the way nodes move in the simulated area. We may include different informative metrics at configuration layer like- network size(number of nodes), network density, capacity, connectivity structure(average number of neighbors, transmission range), mobility pattern(speed, range, direction, frequency, etc.), link bandwidth(bps), traffic pattern(packet size, transmission frequency, type of traffic), link characteristics (bidirectional or unidirectional), transmission medium (single vs. multichannel), and so on.

Commonly used network performance metrics include network settling time, network join time, network depart time, route acquisition time, memory required, number of data packets delivered correctly, energy consumption, as well as associated mean, variance, and distribution, and so on. QualNet, a network simulation tool, achieves real time simulation speeds. Real-time network simulation means that the network can be modeled in parallel with other tools. QualNet Design Mode allows users to set up terrain, network connections, subnets, mobility patterns of wireless users, and other functional parameters of network nodes. Quality of Service modeling capabilities for multimedia and mission-critical applications enables incremental "what if" scenario testing to identify conditions that threaten service level performance.

Protocol layer

Due to the significant difference in MANETs, the mechanisms for wired networks cannot be mapped to MANETs directly. The routing protocol in the network layer locate a path satisfying QoS requirements and responds to route breakdown.

B. Assumptions

QoS provisioning in MANET is a multi-layer problem which requires the mutual support and integration of network layers for supporting real time applications. Batteries form the major component of mobile devices deployed for mobile ad hoc networks. Their make (model) and usage pattern determine MANET lifetime. Battery modeling is helpful in predicting and extending the lifetime of the battery for longer use of battery-operated portable device. A selection of best battery model may prove to be useful alternative. Node's energy can enhance the lifetime of MANETs for routing protocols implementation in real –time applications. Energy consumption at transmit, receive and idle mode for different routing protocols differ under varying mobility models, routing protocols, battery models, traffic types and network configurations. Mobility model greatly impacts the performance of ad hoc routing protocols, including the packet delivery ratio, the control overhead and the data packet delivery.

Mobile ad hoc scenario and the assumptions made for the simulation have a significant impact on the results. Different QoS metrics find place at different layers like Throughput , end-to-end delay, jitter at network layer; link reliability, link stability and node relative mobility at Link and MAC Layer ; node residual battery charge at Physical Layer. Routing protocols behave in a different way under diverse battery models providing unlike throughput values for performance metrics under study.

C. Network Resource

We are listing some network resources and impact of their characteristics on QoS provisioning:

- *Node Buffer Space (memory)* – Data packets must be buffered while awaiting transmission. Furthermore, when buffers are full, any newly arriving packets must be dropped, contributing to packet loss rate.
- *Node Battery charge*- This is the most critical resource, since if a node's battery is drained, it cannot function at all. Node failures can also cause network partitioning, leading to a complete network failure and no service provisioning at all.
- *Channel capacity*- MANET nodes must communicate on the same channel to discover network topology.
- *Minimal Overhead*- The wireless link capacity, battery and computational resources in a wireless multi-hop network are quite limited. Therefore, a QoS Model for wireless multi-hop networks should minimize the

signaling overhead as well as the computational overhead entailed in provisioning of QoS.

- *Robustness*- QoS Model should be capable of handling request route failures and dynamically changing network topology.
- *Fairness*- A fundamental requirement of any QoS mechanism is a measurable performance metric. Typical QoS metric include available bandwidth, packet loss rate, packet filter, estimated delay, hop count and path reliability.
- ***Node Mobility***- this factor generally encompasses several parameters i.e. the nodes' maximum and minimum speed, speed pattern and pause time.
- Network Size, Number, type and data rate of Traffic Sources –a smaller number of traffic sources results in fewer routes being required.
- ***Network's Role***- is to please as many users as possible by providing an all round high QoS. Another goal is to increase the network lifetime, by spreading the battery usage to avoid node failures and network partitioning. However, each individual user or data session has its own specific requirements, and to satisfy the user, the network must match their requirements.

V. Verification of Model

A. Methodology Adopted

We have performed simulations with reactive routing protocols (AODV, DSR, DYMO) under DURACELL AA and DURACELL MX-1500 Battery Models with 11 nodes and five constant bit rate traffic applications using packet size of 512 bytes in QualNet 5.0 as shown in Fig. 3. Transmission current, Reception Load and Idle current load are 20mAmp, 15 mAmp and 10 mAmp respectively.

B. Results and Discussions

We found a clear relationship between these protocols for energy consumption at different modes and different variables set for different layers as shown in Table 1.The study has evaluated three routing protocols for different battery models in physical and application layer of network. From simulation results, it has been observed that DSR provides maximum throughput followed by DYMO and AODV.

VI. Conclusion and Future Work

This paper is based on considerable simulation study on AODV, DSR and DYMO routing protocols for verifying proposed model. In AODV the nodes stay awake at all the time, and the extra energy consumed can thus be fully accredited to the added amount of traffic and the higher degree of packet collisions that occur in high density simulations as the route discovery process in AODV is global. The result will vary on selection of different combinations of parameters at different layers.

The model has some limitations also. It is designed and tested for smaller networks only, with considering any security aspects. We have worked only with mobility models, battery models and energy models for few number of CBR traffic sources only. This QoS model is significant for mobile ad hoc networks having routing one of its vital component. Issues which need further exploration are use of location, mobility, power consumption, probability of resource and route availability. Thus, this model could be extended to include more layers and parameters for its better deployment.

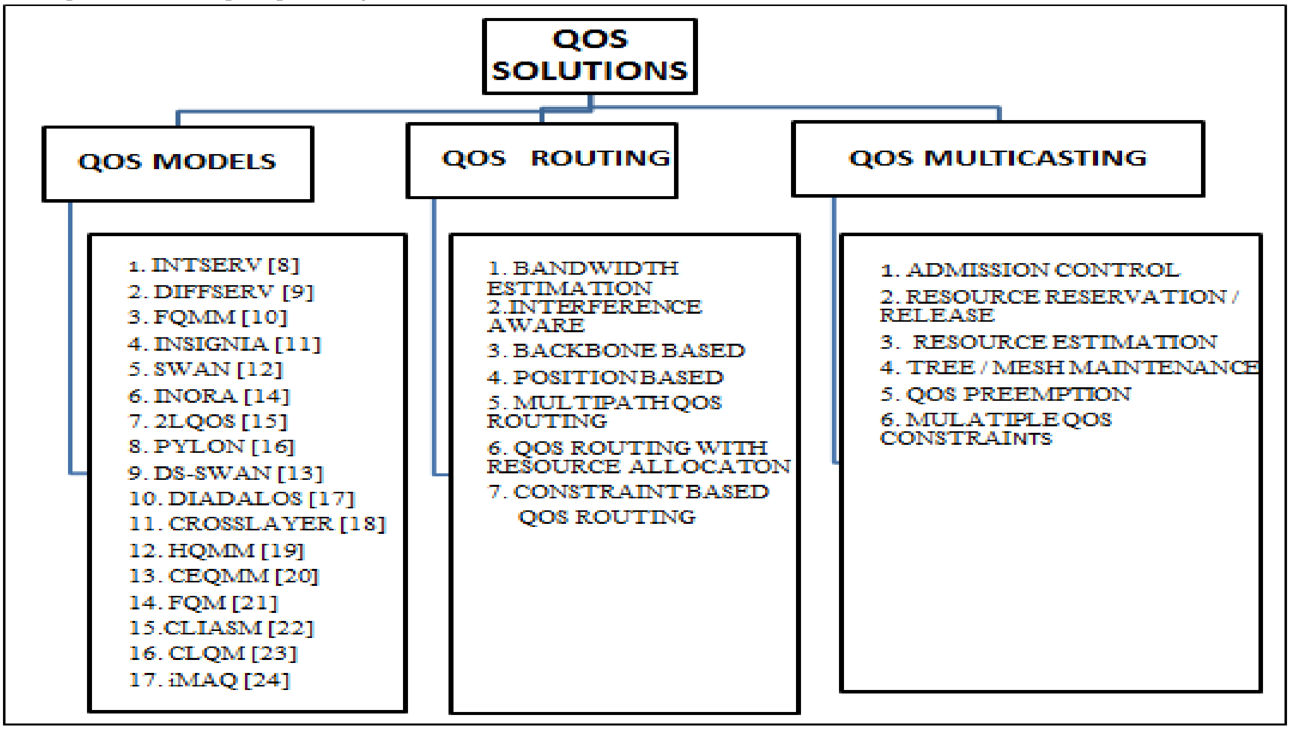

Figure 1. QoS Solutions for mobile ad hoc networks

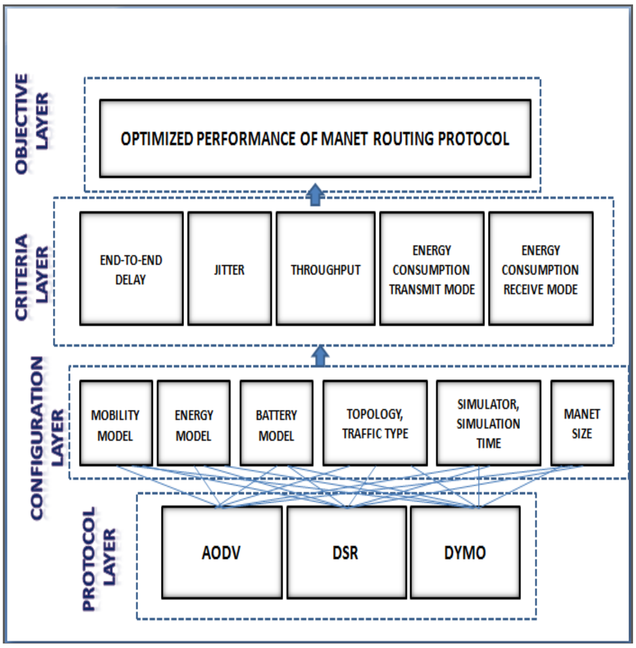

Figure. 2 A Four Layered QoS MANET Model

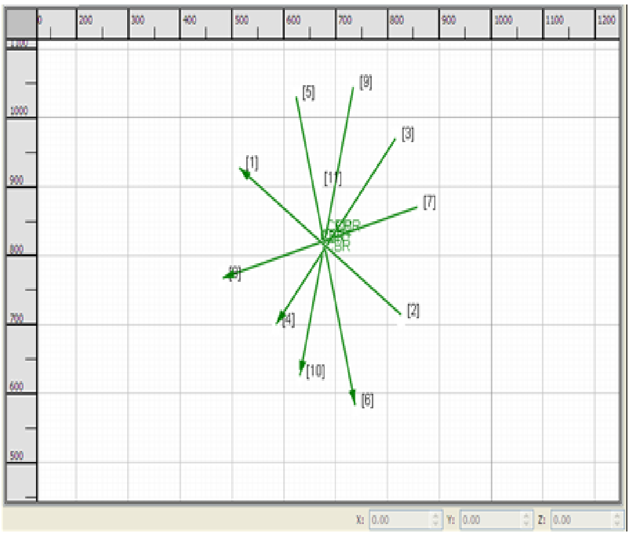

Fig. 3. Simulation Scenario snapshot in QualNet 5.0

Table 1. Performance comparison of protocols.

Battery Model	Energy Consumption in Transmit Mode	Energy Consumptio n in Receive Mode	Energy Consumption in Idle Mode
Residual Life Estimato r Battery Model	DSR>DYMO >AODV	DSR>DYM O>AODV	AODV>DY MO>DSR
Residual Life Estimato r Battery Model	DSR>DYMO >AODV	DSR>DYM O>AODV	AODV>DY MO>DSR

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