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A Novel Quality of Service Monitoring for Mobile Ad Hoc Networks

Yazeed Al-Sbou

Department of Computer Engineering, Faculty of Engineering,
Mu'tah University, P.O. Box: (7), Al-Karak, Postal Code 61710, Jordan

Abstract: The emergence of multimedia networking and computing, Quality of Service (QoS) monitoring and analysis have long been of interest to the networking research community especially over mobile ad hoc networks (MANETs). MANETs poses a significant challenge in its QoS monitoring due its infrastructureless and mobility nature. Current QoS monitoring solutions have primarily been designed to measure one or more of the QoS metric(s) without taking into account the robustness of the proposed approaches of the infrastructureless nature of MANETs. This paper proposes a QoS monitoring infrastructure (QoSMI) for MANETs based on a QoS virtual backbone (QoS-VBB) that can be used for robust QoS monitoring. The proposed QoSMI includes three main steps: First, constructing the QoS-VBB nodes which are mainly selected based on stability for each node, second, measurement of the QoS using an intelligent fuzzy logic assessment approach, third, monitoring the QoS. The monitoring approach involves measuring the main QoS parameters (delay, jitter and packet loss) and uses them as inputs to the fuzzy system, taking into account the QoS parameters requirements of the multimedia application transmitted over the network. Then, the assessment system combines these measurements and produces an output that represents the instantaneous QoS. Every node (dominatee) involved in the monitoring process should assess the QoS of the multimedia application and then forward it to its cluster-head node (dominator or VBB node). This QoS-VBB has proactive maintenance capability which makes it suitable for dynamic network MANETs.

Key words: Quality of service · Fuzzy logic · QoS monitoring · Ad-hoc networks · Virtual Backbone · Node Stability

INTRODUCTION

Nowadays, it is obvious that the evolution of wireless mobile networks and multimedia applications are growing which introduces new challenges in supporting predictable and reliable communication performance. These challenges are consequences of the vastly increasing number of current and future multimedia products that find application not only in wired and fixed wireless networks but also in the mobile environment.

Wireless mobile ad hoc networks (MANETs) have become a rapidly growing field today. Basically, MANETs are composed of mobile hosts communicating with each other through wireless links. Applications of MANETs occur in situations such as emergency search-and-rescue operations, meetings or conventions in which ad hoc networks need to be deployed immediately without base stations or wired infrastructures. These networks are typically characterized by scarce resources (e.g. bandwidth, battery power, processing and storage limitations, etc.), lack of any backbone infrastructure, high error rates and a dynamic topology.

A challenging but critical task that researchers tried to address over the past few years is the development of monitoring and management schemes that suit the characteristics of these networks. To grant and sustain QoS, it is necessary to include a process to monitor the QoS and manage the available resources of the entire network. In general, network management is a service that employs a variety of tools, applications and devices to assist human network managers in monitoring and maintaining networks [1].

Network performance monitoring is an absolute prerequisite for network management because network manager can not hope to manage and control the network unless he/she can monitor its performance [2]. Therefore,

Corresponding Author: Yazeed Al-Sbou, Department of Computer Engineering, Faculty of Engineering, Mu'tah University, P.O. Box: (7), Al-Karak, Postal Code 61710, Jordan.

in order to assess the network and user behaviors and to provide QoS to as many costumers as possible, the networks status should be observed through a monitoring system. This system should obtain measurement data from the network in order to verify whether the QoS performance guarantees (negotiated between a customer and a service provider) committed in the Service Level Agreement (SLA) are in fact being met [3].

Therefore, these tasks can be integrated into a scheduler (as a QoS control mechanism) to measure performance of on-going flows and the measured statistics can be used to control packet scheduling and admission control [4]. Many applications of MANETs have strict QoS requirements for their communications systems, making MANET QoS provisioning mechanisms very crucial for supporting multimedia communications such as real-time audio and video [5]. However, QoS provisioning and awareness in MANETs is quite tough due to the dynamic network topology, unpredictable communication medium, limited battery life of mobile devices, traffic and fairness among nodes, constrained bandwidth, risks of route failure [6]. Therefore, it is essential to monitor the available resources and most importantly to compare them with customer's QoS requirements. Additionally, monitoring systems can be very helpful in QoS routing and multimedia streaming adaptation [7].

Due to the dynamic topology in MANETs, there is no clear definition of what is core, ingress or egress router [8]. In addition, this feature may affect QoS guarantees provided by the network because any change in the topology of the network may require to rediscover the routes which will add some delays or the amount of resources required by the flow or application is no longer available and thus affecting the QoS [9]. Therefore, another issue involved in the provision of QoS in MANETs is how to tackle changes in the QoS due to topology changing. The main objective of this work is to build a QoS monitoring infrastructure (QoSMI). This infrastructure relies on decreasing the number of nodes that participate in the monitoring process. Therefore, we study the impact of overlaying a virtual backbone (VBB) on MANETs and performing traffic monitoring process via this VBB. The VBB should have a minimal number of nodes and should support an efficient and robust means of information collection from all nodes in the VBB. In other words, QoSMI searches for a set of nodes by which will form the VBB and, most interestingly, this VBB will serve as the infrastructure backbone of the network even though MANETs are infrastructureless networks.

After building the VBB and in order to perform QoS monitoring, QoS must be measured firstly. The proposed approach for measuring QoS is based on fuzzy logic. In this work, fuzzy logic will be used to combine the QoS parameters of multimedia traffic, such as delay, jitter and packet loss. The output of the fuzzy system will represent the QoS level provided to the application based upon the network conditions compared to the QoS level expected for that application [10-11].

In this paper, the use of fuzzy logic is justified by the absence of simple mathematical models or formulas to estimate the overall QoS. QoS assessment is a domain, where the application of this approach may be considered appropriate. That is QoS assessment is a domain where the relationship between the input parameters and the output QoS exist but may be complicated. Fuzzy logic simplifies this complexity in the input-output relationship. Additionally, its processing is not intensive; hence, it can be used in each node without affecting its original processing and routing roles [7].

Therefore, using the fuzzy logic QoS assessment system, approaching the QoS monitoring problem using VBBs and constructing the QoSMI represent a logical step towards addressing the MANETs QoS monitoring taking into account its dynamic nature due to mobility. Mobility is one of the main reasons for MANET links to be broken, therefore, the monitoring process will be drastically affected unless the proposed QoS monitoring scheme is mobility-aware. In such cases, the connectivity between the VBB nodes must be sustained, whenever possible to maintain operability.

In summary, this paper presents a QoSMI which will be the core of network performance/QoS monitoring. Successful QoS-VBBs need to posses the following features: robustness, efficiency of construction, ease of maintenance and competitive performance measures. The proposed QoSMI approach will ensure proper operation of the network, track the ongoing QoS, compare the monitored QoS against the expected performance, detect possible QoS degradation and then tune network resources accordingly to sustain the delivered QoS [12]. These represent the basic gaols of any proposed QoS monitoring system.

QoS Monitoring Mechanisms and Architectures

QoS Monitoring Mechanisms: According to the QoS information that can be obtained from monitoring systems, the mechanisms for QoS monitoring can be classified into two categories, end-to-end QoS monitoring and distributed QoS monitoring [13]. The end-to-end monitoring approach only gathers information of the flow QoS from both endpoints; sender and receiver. On the other hand, distributed QoS monitoring approach collects information about the monitored flows from different network segments crossed by these flows. Clearly, both approaches can detect possible QoS degradation of the flow by consolidating the retrieved traffic [12]. But, distributed monitoring is more comprehensive than the end-to-end approach because it provides more information about the degradation because flows usually cross different network sections which may be different in their available resources and so every section will provide different QoS levels. The fundamental QoS monitoring mechanisms include the following: QoS measurement, QoS maintenance, QoS degradation and QoS monitoring availability [14]. The proposed monitoring approach (QoSMI) will try to include all of these operations in the implementation step.

Monitoring Architectures: One of the challenges of designing a monitoring infrastructure for MANETs is how to construct abstractions which are able to capture the properties of ad hoc network [15]. MANETs monitoring structures can be configured as:

Centralised: Centralised monitoring relies on a single monitoring node (manager station). This node is responsible for monitoring the whole network nodes. This type of monitoring is only suitable for small networks. If the monitoring node fails, the monitoring system collapses. This type is shown in Figure 1.

Hierarchical: The hierarchical monitoring uses multiple monitoring nodes with one of them acting as a central manager. MANET is divided into clusters. Each cluster elects a cluster-head (intermediate manager). This intermediate manager is responsible for monitoring the nodes in its cluster (domain). All the intermediate managers are connected to a top monitoring station as shown in Figure 2. This type of structures is suitable for large networks.

Distributed: Distributed monitoring relies on multiple management nodes. In this type, network nodes are collected in clusters as in hierarchical system and the nodes in each cluster elects a cluster-head node. Each cluster-head is responsible for monitoring the nodes in its domain. Cluster-heads communicate with each other in a peer-to-peer manner as shown in Figure 3.

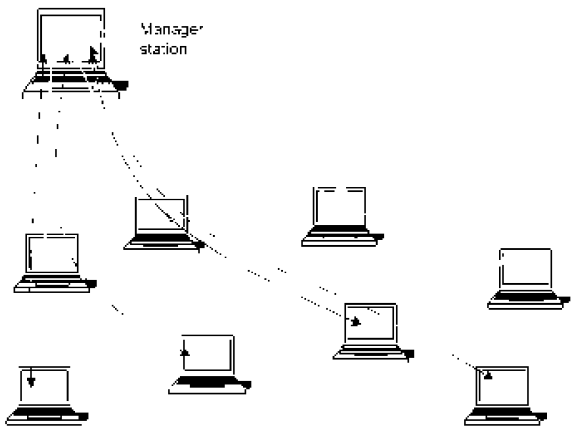

Fig. 1: Centralized monitoring architecture

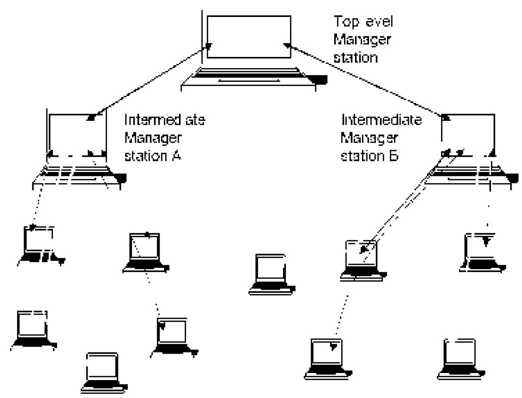

Fig. 2: Hierarchical monitoring architecture

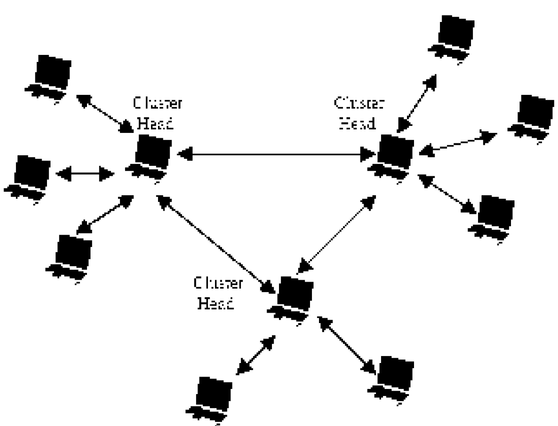
Fig. 3: Distributed monitoring architecture

The QoSMI will fulfil both hierarchical and distributed as will be shown later in this paper when constructing the VBB structure.

Related Work: Several approaches have been proposed in the literature for QoS monitoring and network management solutions over conventional networks.

One of the main standards proposed for the wired network management is the Simple Network Management Protocol (SNMP) [16]. SNMP was based on two main components, manager and agents. The manager is a device which supervises the network and stores the gathered measurements and information while the agents are the nodes being managed. Another powerful approach is the remote network monitoring (RMON) [17]. RMON designed to collect real-time data on LAN. It is used to monitor the network traffic in specific location to provide the network manager with information regarding important events in the network before they result in a crash.

Among the pioneering approaches for the management of ad hoc networks, the Ad hoc Network Management Protocol (ANMP) [18]. This SNMP-compatible management architecture is based on node clustering using specific clustering algorithms. Then a three-level hierarchy (manager, cluster-heads and simple nodes) is constructed. The simple nodes collect the information locally and then send it to the cluster head. The cluster heads filter the required information and submit them to the overall manager.

The GUERILLA framework is a self-management approach for ad hoc networks [19]. This was proposed to solve the problem of unpredictable behaviour of the MANETs. The management tasks are spread over the network nodes according to their capabilities to form a management hierarchy. Based on the available resources in each node, GUERILLA, after clustering, classifies these nodes in each cluster into three levels: nodes with lowest levels of resources that are only serving as information collection agents (like the SNMP agents), nodes with enough resources which actively probes the SNMP agents to poll the stored information and nomadic managers nodes that maintain connectivity in the management plane with other nomadic managers.

In [20], Intrusion Detection Systems (IDS) for ad hoc networks have been proposed to monitor and detect network attacks and misbehaviour performances based on distributed schemes of network monitoring.

In [15], a resource monitoring architecture for mobile ad hoc networks is presented. The system was based on the abstractions of neighbourhood and swath to cope with the range of parameters of interest to an application and separate the resource monitoring system into an extensible infrastructure and specific sensors, which record network parameters of interest. The resource monitoring system presented was structured into a common infrastructure for resource monitoring that leaves the details of performance measurement and processing to the clients. This approach decouples applications (and other users of resource information) from the details of the information gathering. Preliminary experience indicated that the monitoring system is agile enough to run in a highly mobile ad hoc network.

A monitoring algorithm in OLSR-based ad hoc networks was presented in [21]. This was proposed to collect parameters from nodes without consuming the network resources. It was shown that the proposed approach greatly reduces problems associated with monitoring and data collection in wireless networks compared with other monitoring approaches.

In [8], the authors proposed a QoS architecture for bandwidth management and rate control in MANETs. In this architecture, each node will continuously estimate its available bandwidth. The bandwidth value will then be used by the source nodes for QoS capable routing protocols to provide support to admission control based on allocating weights to individual links on the basis of the metrics link quality, channel quality and end-to-end delay. In addition to this, a rate control mechanism is used to regulate best-effort traffic, whenever network congestion is detected.

In [22], QoS monitoring solution that uses a model driven approach to service modeling, data mining techniques and network level key performance indicators from probes was described. The data mining technique uses its own engine and learnt data models to estimate QoS values and feeds the estimated values to the modeling engine to calculate SLAs. In [23], a design of distributed QoS monitoring and adaptive modules for multiple workflows in adaptive service-based systems (ASBS) was presented.

In summary, several researchers have suggested various QoS monitoring approaches from different perspectives and revealed that QoS monitoring can be achieved if certain conditions or assumptions are satisfied. The differences of the proposed approach from others are: firstly, it is based on constructing VBB system depending on the node stability measure; secondly, it uses a QoS assessment approach which provides a QoS value which represents the summary of the QoS metrics, while other approaches just monitor one QoS metric individually like delay, jitter, or losses. In addition and due to MANETs mobility, the proposed monitoring system has a dynamic maintenance which is responsible for keeping the VBB continuously connected. That is, if the VBB is disconnected from any of its parts, it must be repaired and connectivity restored.

Monitoring Approach Using The Virtual Backbones (VBB): Generally, the QoS problem is intricate [24]. When it comes to MANETs, the problem becomes more complicated [25-27]. The added complexity follows logically because of the special characteristics of the MANET networking platform and the continuous monitoring of the QoS metrics. This monitoring must be continuously sustained causing high overhead [28]. To reduce this overhead, this paper will use a robust QoS infrastructure, or backbone, algorithm which mainly constructs a stability-aware QoS-VBB for QoS monitoring purposes. In addition to node rank identifier (*RID*), this QoS-VBB extracts a maximal independent set (*MIS*) which integrates a node stability measure, s_n, in the selection process of the *MIS* nodes. This develops a construction process to build a connected dominating set (*CDS*).

Providing an efficient, robust and low-overhead QoS monitoring system in MANETs based on the QoS-VBB is the spirit of this paper. To achieve this, a novel type of VBBs is devised. For a MANET graph $G(V,E)$, a dominating set (*DS*) is constructed [25]. Essentially, the *DS* nodes are carefully selected and then suitably connected together in order for this new structure to serve as the MANET's QoS-VBB. These nodes are referred to as dominators. Each dominator and all its dominatees are members of what is called a domain. Notice that each dominator node also dominates itself. The *DS* nodes are connected to form a QoS *CDS*. A *CDS* of G is a subset V' of V, such that each node in the complementary subset, $V'' = V - V'$, is adjacent to at least one node in V', where V' induces a connected subgraph. To summarize, the original graph is represented by a lesser number of nodes that are required to propagate information. It is essential to use a relatively small number of MANET nodes in the QoS monitoring computation process. This is due to the fact that the overall control-traffic to perform the main monitoring functionalities needs to decrease to maintain tractability. Indeed, VBBs and their design in MANETs have been the subject of some studies and proposals [28-30].

Mobility Analysis of MANETs: Algorithmic Description: The impact of mobility on MANET performance and QoS monitoring is critical where, network performance tends to degrade due to the network members mobility. Due to the mobility nature of MANETs, the network topology is changing continuously. Consequently, the proposed monitoring algorithm considers the selection of the most stable nodes in their domains to serve in a VBB which in turn is employed to enhance the robustness of the QoS monitoring process. Therefore, the study considers a node stability measure rather a node mobility measure.

This section concentrates on the approach of quantification of individual node stability in MANETs. We refer to the individual node stability by s_n where the subscript n refers to the *RID* of the node. Hence, the measure, s_n, used in this research is a stability measure that reliably represents node n as an interactive measure of node n in conjunction with its links to all 1-hop neighbours. Consequently, s_n is a measure that is based on the future prediction of all direct 1-hop links behaviour. Thus, it is a measure that relies on the prediction information of links availability rather than their history.

QoSMI represents a robust stability-based QoS monitoring solution. It relies on an integrated type of VBBs. The structure of QoSMI monitoring agent is simplified in Figure 4.

The algorithmic detailed description of the QoSMI agent is as follows.

MIS Construction Phase: The definition of the *MIS* implies that for any graph G, if a node is not in the *MIS*, then it must be adjacent to at least one of the nodes in the *MIS*. Thus, the *MIS* of any graph is an independent dominating set (*IDS*). For a MANET, the nodes of its *MIS* are referred to as dominators and the rest of the nodes are referred to as dominatees.

In QoSMI, we construct a new *MIS* type where its nodes are primarily selected based on the stability conditions of the network nodes. This set of stability-aware nodes represents the core members of the VBB. In addition to node stability, the RID_n is considered in the *MIS* construction. The stability of a node n is judged by using the stability measure, s_n. The construction process of our *MIS* is illustrated as follows:

- Each node n, which is initially in the candidate status, broadcasts periodic $Hello_{DS}$ messages to all its neighbours. Each $Hello_{DS}$ message consists of two fields: RID_n and s_n value.
- Once node n obtains all $Hello_{DS}$ messages from all its 1-hop neighbours, it determines the set of neighbours that have a higher rank than its own, if any. We refer to this set as the eligible dominators set of node n, denoted by (D^n_e). Initially, D^n_e is empty. A node u has a higher rank than node n and consequently is added to D^n_e if one of the following cases applies:

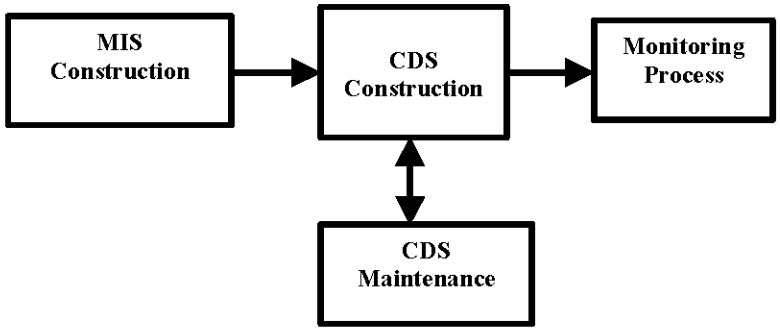

Fig. 4: QoSMI monitoring agent

(a) $s_u > (s_n + s_{th})$
(b) ($s_u \geq (s_n - s_{th})$ and $s_u \leq (s_n + s_{th})$) and $RID_u < rRID_n$.

- Each node n with a nonempty D^n_e, nominates the candidate node u which has the lowest RID of it's D^n_e as its dominator. This nomination takes place by sending a DOMINATEE message addressed to node u.
- Whenever a node u receives a DOMINATEE message from node n, it has the following possibilities:
- If its D^u_e is empty, it accepts the nomination and becomes the dominator of node n by sending a unicast DOMINATOR message to node n.
- If its D^u_e set has at least one node, it waits until it receives a response from its nominated potential dominator, then:
- If its potential dominator becomes a dominatee, it nominates the candidate node (if any) with next lowest RID node in its D^u_e set, as a potential dominator. If all its potential dominators have become dominatees, it accepts domination of node n and declares itself as a dominator by sending a unicast DOMINATOR message to node n.
- If it receives a DOMINATOR message from a potential dominator, then node u switches its status to dominatee. Therefore, the received DOMINATEE message from node n is implicitly rejected.
- Once node n receives a DOMINATOR message, it switches its status from candidate to dominatee.
- Whenever a candidate node n realizes that all its neighbours have become dominatees, it declares itself as a dominator.

CDS Construction Phase: The resulting *MIS* or *DS* from the previous subsection must be connected to form a QoS-CDS or a QoS-VBB. A *CDS* of a MANET must guarantee full connectivity of all *EDS* nodes. A fully connected graph $G(V,E)$ is a graph in which any node n can find a path to any other graph node throughout the graph links. Consequently, if this full connectivity of the *EDS* nodes is guaranteed, all $G(V,E)$ nodes will be able to reach each other through *EDS* nodes [26].

VBB-QoS Maintenance Phase: Providing a consistent QoS performance in environments with dynamic nature, such as in MANETs, is a key robustness feature of any QoS infrastructure. Varying mobile network dynamics can be due to many reasons. In MANETs, node mobility is a common source of network dynamics variations.

CDS maintenance is responsible for keeping the QoS-CDSs continuously connected while node mobility is low or moderate. That is, if the VBB is disconnected from any of its parts, it must be repaired and connectivity restored. Due to the distributed fully localized and self-healing nature of the design of our QoS-*CDS* construction algorithm, the maintenance process is interestingly simple; however, this simplicity does not sacrifice algorithmic efficiency. *CDS* maintenance requires that the *DS* and its properties be kept intact. Whenever a dominatee node loses all dominators in its vicinity, it must change its status to a candidate. When a local group of candidate nodes learn about each other, the same procedures for building a QoS-CDS are followed in the local area. Dominators simply update their tables and lists accordingly.

QoS Monitoring Process: After creating the VBB, every dominatee node in this structure, periodically, assesses the QoS of the multimedia application passes or destined in it and initiates a unicast QoS message to its dominator which contains the measured QoS. This assessment is achieved using a fuzzy measurement system [10-11].

Fuzzy logic is a powerful tool for decision-making process involving information characterized by imprecision and uncertainties. Fuzzy set theory was first proposed by Lotfi A. Zadeh in 1965 [31]. A great advantage of the fuzzy system is that for complex problems it tends to be less computational intensive than other intelligent methodologies [32]. Therefore, it is quite suitable for evaluating the end-to-end QoS measurements where the uncertainties and requirement of combination of more than one parameter (input) are present. The fuzzy logic approach employment is also justified by the nonlinearity and absence of mathematical model to estimate the QoS measurements. Because fuzzy logic processing is not heavy, it can be executed in each node without interfering its router performance [7].

Measurement Approach: QoS Assessment Fuzzy Logic System: In order to monitor the QoS, it should be firstly measured. The use of an intelligent method for measurement and evaluation of the QoS is described in this section. A performance measurement method for estimating the QoS of multimedia application experienced by the network users has been proposed based on fuzzy logic [10-11]. As an example, the proposed QoSMI system will used for monitoring the QoS of time-sensitive multimedia applications like audio or videoconferencing. The proposed fuzzy system consists of fuzzy inputs, fuzzy rules, fuzzy reasoning and fuzzy outputs.

For time-sensitive multimedia applications, the QoS level is mainly affected by delay, jitter and loss parameters. These parameters will be quantified and used as input variables to the fuzzy inference system. The fuzzy input variables were represented by three fuzzy sets to create the input membership functions depending on QoS requirements of each input variable to form the fuzzy linguistic variables as Low, Medium and High. Each input parameter will be mapped to these fuzzy sets according to its QoS value.

Here, a single fuzzy output will provide the assessed QoS. Hence, the output of the fuzzy system is set as the indicator of how the network dealt with the application. In addition, the fuzzy output variable will be split into three singleton fuzzy sets. The corresponding fuzzy linguistics variables are Poor (for poor QoS), Average (for average QoS) and Good (for good QoS).

For constructing the fuzzy inference system, Gaussian membership functions are used for the input and output variables of the fuzzy system. This type of membership functions is chosen because of its smoothness, computing simplicity and concise notation. In addition, it is the most widely used membership function in the literature and it is popular method for specifying fuzzy sets [31]. Gaussian membership function requires the mean and the standard deviation values to be defined for every parameter (input and output) of the multimedia applications subjected to assessment. These values are selected based on the QoS requirements of each QoS parameter to provide reasonable outputs to reflect the overall QoS of the application.

Fuzzy logic system needs a set of rules to be defined. These rules are used to determine the relationships between the input and output parameters of the fuzzy inference system. The number of rules depends on both the number of input variables and the number of fuzzy sets associated with each input variable. In our fuzzy system we will have nine rules resulting from the combination of the three inputs (delay, jitter and losses) each having three fuzzy sets as shown in List 1. Each combination corresponds to a specific output depending on the measured values of the input parameters. In this List, L is low, M is medium, H is high, P is poor, A is acceptable and G is good.

The fuzzy reasoning will be based on the minimum-maximum (min-max) inference method, where the crisp input values are mapped into the membership functions (fuzzification) and assessed according to the rules in the place. Each rule is applied to the corresponding membership functions and the minimum (min) of them is mapped into the associated output membership function. Then the output of each rule will be aggregated (max) into the defuzzifier that gives the final crisp value that indicates to which output fuzzy set the outcome has to be assigned. A detailed description for the QoS assessment in terms of fuzzy inputs, rules, fuzzy reasoning, fuzzy outputs and membership functions can be found in [10-11].

If (Delay is L) & (Jitter is L) & (Loss is L) ⇒ (QoS is G)
If (Delay is L) & (Jitter is L) & (Loss is M) ⇒ (QoS is G)
If (Delay is L) & (Jitter is M) & (Loss is L) ⇒ (QoS is G)
If (Delay is M) & (Jitter is L) & (Loss is L) ⇒ (QoS is G)
If (Delay is L) & (Jitter is M) & (Loss is M) ⇒ (QoS is A)
If (Delay is M) & (Jitter is L) & (Loss is M) ⇒ (QoS is A)
If (Delay is M) & (Jitter is M) & (Loss is L) ⇒ (QoS is A)
If (Delay is M) & (Jitter is M) & (Loss is M) ⇒ (QoS is A)
If (Delay is H) or (Jitter is H) or (Loss is H) ⇒ (QoS is P)

List 1: Fuzzy rules inputs and output

To summarize, after getting the QoS parameters, the parameters values will be used as inputs to the first stage of the fuzzy system (Fuzzifier). After feeding the fuzzy system by the QoS parameters, an output value will be produced which represents the evaluated QoS of each multimedia application. The measured QoS values will be in the range [0, 100]%. This output characterizes how the network dealt with the application.

The output QoS vector will contain values between zero and 100%. These values will be categorised symmetrically into three regions to represent the QoS level. These regions were poor, average and good QoS regions. The categorisation process is based on two thresholds, which are 33% and 67%. These thresholds will be used as follows:

- If the QoS value is less than or equal to 33% ⇒ the QoS is in the poor region,
- If the QoS value is greater than 33% and less than or equal 67% ⇒ the QoS is in the average region and
- If the QoS value is greater than 67% ⇒ the QoS is in the good region.

Each dominatee (node) in the (*CDS* or *MIS*) should measure the QoS parameters (delay, jitter and loss) and assess the instantaneous QoS based on the proposed fuzzy logic system. Every assessed QoS value should be reported in a unicast message to the dominator which it belongs to. The importance of the proposed monitoring system stems from the fact that the dominatee nodes do not need to measure and submit each of the measured QoS parameters to the dominate node in a separated message. But, in stead it just needs to send a single value (i.e., the assessed QoS) which represents the combined value of the measured QoS parameters. Because sending every instantaneous measured parameter to the dominatee node will overwhelm the network and degrade its performance. Therefore, by gathering the measured QoS values from the dominatee nodes in every *MIS*, the QoS of every application can be monitored instantaneously, if different applications are running over the MANET, then different fuzzy system arrangement (input, output, rule and requirements) should be identified depending on the nature of the multimedia application in terms of the QoS parameters that affects the behaviour of the given application.

CONCLUSIONS

QoS monitoring over MANETs is one of their intricate issues. The major goals of this paper are of two fold: Firstly, to construct a stable VBB for MANETs. Secondly, to use this structure for QoS/performance monitoring of MANETs behaviour based on an intelligent measurement system. In total, a QoS monitoring infrastructure (QoSMI) was built. QoSMI is a stability-aware Q oS monitoring system, which requires each node to compute its own stability measure. The success of our monitoring system stems from the fact that the robustness is related to the reality that it utilizes a stability measure that predicts the network connectivity during its early construction stages for the purpose of constructing a stable VBB. Furthermore, the proposed monitoring system has a dynamic maintenance which is responsible for guaranteeing that the VBB continuously connected. That is, if the VBB is disconnected from any of its parts, it must be repaired and connectivity restored.

This monitoring system is not implemented yet. Therefore, the next stage is to implement and validate the QoSMI system and study the effect of network mobility conditions on network MIS size, QoS-VBB computation time, QoS-VBB lifetime, QoS measurements computation time and their overhead.

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