SNR-Based Virtual Base Station for establishing a QoS Framework in MANET

Imane M. Amin	Prof. Dr. Imane Aly Saroit	Prof. Dr. S. H. Ahmed	Dr. Laila Nassef
imane.fahmy@gmail.com	i.saroit@fci-cu.edu.eg	s.hanafy@fci-cu.edu.eg	lnassef@hotmail.com

Abstract

Multi-hop Mobile Ad-Hoc wireless Networks (MANET) became commonly used in military and commercial applications. Therefore, to ensure a satisfactory network performance - according to the user's applications requirements - we have to meet the most challenging QoS parameters in MANET environment. One of the most challenging issues in MANET is the lack of central coordination. Related studies dealing with QoS provisioning in MANET have suggested Virtual Base Station (VBS) election algorithms to select one Mobile Terminal (MT) or node to be a central coordinating and routing node or device for the other network's nodes. These previous studies have built their algorithms based on: Max-Min d-cluster formation, or the battery residual power. The VBS protocol was invented in MANET in order to simulate the regular cellular network's routing device and act as a central administrative point to relay the packets transmitted between the nodes. Since MANETs are commonly used in emergency applications that require a satisfactory QoS for almost all their users, thus, the improvement of the overall network's throughput can be useful to establish a promising QoS framework once the proper integration of the MAC protocol with the routing and call admission mechanisms is established. This paper suggests an algorithm to elect the VBS based on the Signal to Noise Ratio SNR to reduce the "Packet Loss Ratio" and therefore improve the network's throughput in (MANET).

1. Introduction

The main purpose behind using the infrastructure-less MANET is the ability to transmit packets between the communicating nodes in a quick and economically less demanding way. They allow anywhere, anytime network connectivity; therefore, in the absence of a fixed wired network's infrastructure, we have to make sure that their use will remain as secure and profitable as possible.

In the following sections, we will first introduce the MANET environment in section (2), then the QoS architecture, QoS challenges in MANET, and their solutions classifications are discussed in section (3). In section (4), we will present the proposed algorithm for VBS election based on the nodes SNR followed by its simulation results and future work to establish a promising QoS framework in MANET in section (5).

2. MANET Environment

The MANET represent a special category of wireless mobile networks that utilize multi-hop radio relying (routing) and are capable of operating without any fixed or wired infrastructure support (infrastructure-less). The MANET's major drawback is their difficult routing mechanism and overhead due to the absence of a central coordinator point or a base station during the packets transmission and reception among the mobile devices. MANETs have recently became suitable for different types of applications varying in their QoS priorities from home and road mapping to military and emergent ones due to their quick and easy deployment. Thus, such networks can be used in situations where either:

- There is no other wireless communication infrastructure present.
- There can not be such an infrastructure present or set due to an emergent situation (e.g. military tactics or natural disasters). They are also commonly used with collaborating and distributed computing, wireless mesh networks, wireless sensor networks and hybrid wireless networks.

INFOS2008, March 27-29, 2008 Cairo-Egypt

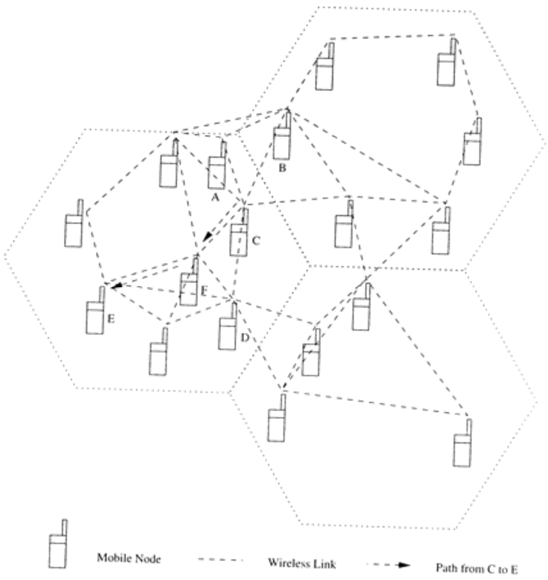

Figure 1. an example of MANET transmission scheme.

In figure (1) as shown in [1], we have a MANET transmission scheme where mobile nodes are communicating through their wireless links and multi-hop routing mechanism to enable packets transmission/reception among them. For example, if node C wants to send/receive packets to/from node E, it should pass by node F to relay its packets to node E (i.e., two-hops).

Some of the issues in MANETs include: Medium Access scheme, routing, pricing scheme, security, energy management, scalability, and QoS Provisioning.

3. QoS in MANETs

Quality of Service QoS is the ability of the network elements (Applications, host, router) to provide an agreed level of communication service between the service user (customer) and the service provider.

The goal of QoS provisioning as stated in [1] is to achieve a more deterministic network behavior, so that information carried by the network can be better derived and network resources can be better utilized.

3.1 QoS Architecture

The QoS parameters that should be provided with the demand level of service or category of calls are primarily: The link's Bandwidth, Delay, Jitter, Packet delivery ratio, Throughput, Security, Reliability, Resources availability, and Energy consumption.

In figure (3), the QoS architecture as shown in [10] that includes all networking layers from the application layer to the MAC layer. The bold lines indicate the flow of data packets and the narrow lines indicate the flow of control packets. To support QoS, the routing protocol should have embedded schemes such as call admission or adaptive feedback. For QoS-aware routing, the current network status information is provided to the application for performance optimization.

The routing protocol at the network layer should get enough channel information from the lower layers so the admission/adaptive scheme can be performed based on the current network status.

The proposed routing protocol in section (4) should guarantee a QoS framework when applied on MANET by choosing periodically (within a certain time interval) -among the network's cell nodes- the node having the stronger Signal to ensure a satisfactory "packet delivery ratio" and hence a lower "packet loss ratio".

3.2 QoS challenges in MANET environment

There are many challenges to establish a promising QoS framework in MANETs such as: Dynamically varying network topology, the imprecise state information, lack of central coordination, the mobility of hosts, the error prone shared radio channel, the limited availability of resources (i.e., bandwidth and battery power) and the insecure medium (especially when using it in military applications).

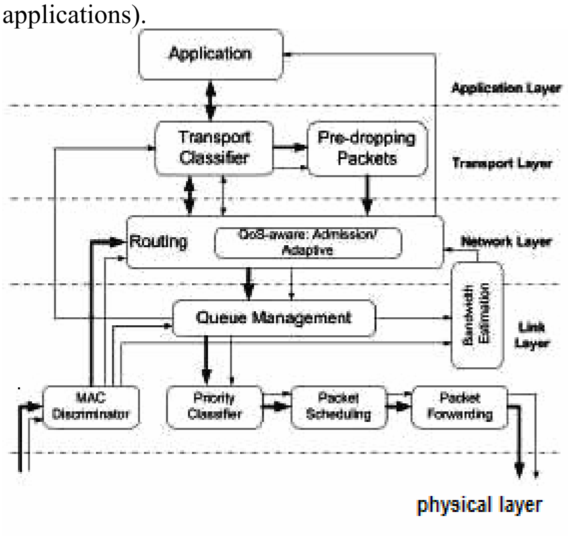

Figure 2. QoS Architecture map on network layers.

In order to support QoS in MANET environment, we have to make sure that the resource reservation schemes employed could be implemented and maintained by all networking layers from the application layer to the physical layer properly. Therefore, establishing a QoS framework requires QoS-aware routing protocol solution.

3.3 QoS solutions classification

There are two commonly used QoS provisioning solutions with the MANETs as presented by [3]:

1) Solutions based on QoS approach employed:
   - Based on interaction between routing protocol and QoS (QoS-aware routing).
   - Based on interaction between routing protocol and the Medium Access Control (MAC) protocol.
   - Based on the routing information update mechanism employed.
2) Solutions based on the layer at which they operate (Layer-wise QoS solution):
   - Medium Access Control / Data Link Layer (MAC/DLL) Solutions.
   - Network layer solutions.
   - Cross-layer solutions.

In section (4), we propose an algorithm for VBS election using the SNR (which can be detected at the physical layer) to act as the MANET central coordinator to route and relay packets received from and transmitted to other nodes. We expect to achieve an improvement to network's throughput at the Network layer by reducing the packet loss ratio.

4. SNR-based VBS election algorithm

4.1 VBS Concept

The concept of a Virtual Base Station VBS election as shown by [2] is to ensure that the routing and the Resource Reservation are achieved and managed through the connection. Therefore, this related study has invented a VBS node to be a central coordinating point. A VBS must be intelligent enough to act as both:

1. A host mobile device (transmitting source or destination device) and
2. A routing device (to route or relay received packets from other nodes until reaching their final destination node in MANET).

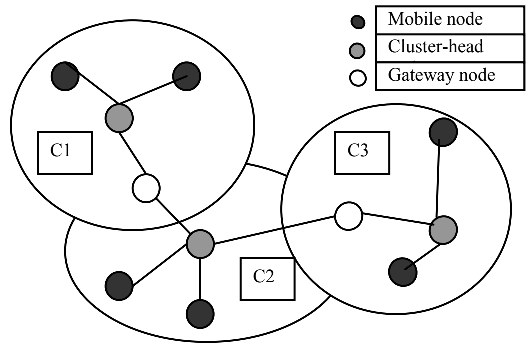

Figure 3. A typical Cluster-head Network.

According to [9], in figure (3) showing a MANET that is divided into three clusters. Each cluster has a "cluster-head" node. The Mobile nodes communicate through their cluster-head node within the same cluster. Each cluster has a "Gateway" node that connects the cluster "virtually" to the other clusters gateways to enable nodes from different clusters to communicate and exchange packets.

The previous work on VBS election has suggested a Power-Aware Virtual Base Station (PA-VBS) election algorithm to choose the convenient node to act as a cluster-head (VBS) at a given time for each cluster of nodes based on its battery residual to reduce energy consumption.

4.2 The PA-VBS algorithm

The PA-VBS protocol reduces energy consumption which is one of the most important goals of the QoS in MANETs. Its infrastructure is mainly based on the residual battery capacity of the wireless mobile terminals. Some of the nodes based on their current residual battery capacity become in charge of all nodes in their neighborhood or a subset of them. If the elected PA-VBS stops sending its periodic "Hello" message for a period of time, a new PA-VBS is elected. Every node has a "Sequence number" for taking proper routing decisions and saving battery energy.

The Max-Power is a constant defined as the minimum required battery capacity for a class-1 user's node to last from the time it had a fully charged battery (for exactly one day) without having to be recharged given all three conditions above. $\mathbf{MP_i}$ is the battery capacity of the node at a certain defined time interval instance i. *The Normalized Max-Power* $\mathbf{(NMP_i)}$is given by:

$$(NMP_i) = MP_i \,/\, \textit{Max-Power}. \quad (1)$$

And then, the *Normalized Power Value* **(NPV_i)** is given by:

$$(NPV_i) = NMP_i / Max\text{-}Power \quad (2)$$

Upon receiving a “hello” message, the node sends back a “merge-request” message to the sender in order to elect the new VBS “if and only if” the node is neither a VBS nor supported by one and it has: $\mathbf{NPV_i < NPV_{Sender\ of\ hello\ message}}$

4.3 SNR-Based VBS election Algorithm

The suggested algorithm here by this paper is proposing a VBS (cluster-head node) election for each cluster of nodes during a specific time interval based on the variation in time of the *Signal to Noise Ratio* (SNR). Thus, the node in MANET with the least variation (ΔSNR) is chosen to become the VBS node because it has the stronger signal transmitted to and received from the other nodes during a given transmission period.

It was shown in [1] that the power required to transmit a packet from node A to node B is inversely proportional to the n^{th} power of the distance (d) between them, that is, $1/d^n$, where n varies depending on the distance and terrain between the nodes. A successful transmission from node n_a to node n_b requires the SNR of the node “b” to be greater than a specific threshold value ψ_b. This can be mathematically represented, which shows that for a successful transmission, the SNR at receiver node n_b given by SNR_b must satisfy the condition given by (1) which is presented by [4] and also referred to by [5],[6],[7],[8]:

$$SNR_b = \frac{P_a G_{a,b}}{\sum_{k \neq a} P_k G_{k,b} + \eta_b} \psi_b (BER) \quad (3)$$

Where P_k is the transmission power of host n_a;$G_{a,b}$ = $1 / (d^n)_{a,b}$ is the path gain between hosts n_a and n_b; η_b is the thermal noise at the host n_b; BER is the Bit Error Rate based on its threshold ψ_b.

For each node, we calculate the variation in signal power over different time intervals and then we calculate the average signal power (SNR in decibel) to represent its threshold. At last, all the node’s thresholds are compared to get the least Threshold that is the threshold of the least noisy node. The node with the least threshold is elected to be the VBS.

Assuming that k is the node’s ID number, ΔP_k is its Power. Then, we can derive the following equations:

$$\Delta SNRk = \Delta Pk\ (nk) \Delta t \quad (4)$$

$$\Delta SNRk = Pk\ (nk)t1 - Pk\ (nk)t0 \quad (5)$$

Where $\Delta t = t_1 - t_0$. t_0 is the initial start-up time and t_1 is the terminating time interval in seconds. (ψ_k) is the threshold (variation in Signal power) at node n_k and N is the Total number of nodes in MANET. Therefore, we can get the Average Threshold of the entire network’s nodes ψ_N: Average Threshold value using:

$$(\Delta\psi_N) = \sum_{k=1}^{N} \frac{\psi_k}{N} \quad (6)$$

If at a certain time interval, we detected that for the same node:

$$SNR(n_k)_{t1} < SNR\ (n_k)_{t1+\Delta t}) \quad (7)$$

Then, we can tell that this node has moved far from the other MANET’s nodes.

For N nodes MANET, we can calculate the Threshold ψ_k for each n_k, where k=1, 2, …, N. We can derive the Average Threshold $\Delta\psi_N$ using formula (6). Then, we calculate the SNR of each n_k: SNR_1, SNR_2, …, SNR_N using formula(3). In order to elect a Virtual Base Station (VBS) during a specific time interval, we should compare each node’s threshold (ψ_k) with the calculated Average threshold ($\Delta\psi_N$) to find the $n_{VBS} = n_i$ where i= ID of the node with the highest SNR (i.e, with the stronger signal propagated during a given time interval)

$$SNRn_i \geq \Delta\psi_N$$

In the following table, we briefly compare the PA-VBS algorithm with the SNR-Based algorithm to specify their idea, VBS election parameter, packet loss, energy management and their routing overhead.

Table 1. Comparison between SNR-based VBS and PA-VBS algorithms:

Characteristics	PA-VBS algorithm	SNR-VBS algorithm
Idea of algorithm	The PA-VBS algorithm is invented to select one of the nodes to act as a cluster-head randomly based on its battery residual.	The SNR-Based VBS algorithm is invented to select one of the nodes to act as a cluster-head based on its mobility within a certain time interval.
VBS election parameter	The Normalized Power Value (NPV)	The Signal-to-Noise Ratio (SNR)
Packet Loss	Is not studied by this algorithm.	It guarantees a lower Packet loss Ratio since the elected VBS has the stronger signal.
Energy Management	Reduces Energy Consumption.	Reduces Energy Consumption

Routing overhead	Low routing overhead since each node is required to only maintain routes to its VBS instead of maintaining all other nodes routes.	Low routing overhead since each node is required to only maintain routes to its VBS instead of maintaining all other nodes routes.

4.4 Simulation results

The Global Mobile Information System Simulator (GloMoSim) package [14] is a scalable simulation environment for large wireless network that uses a Parallel discrete-event simulation capability (Parsec).

As presented by the GloMosim tutorial [12], GloMoSim simulation package is more suitable for ad-hoc networks mobility functions. Its philosophy is to specify the destination point and the time the node will arrive there.

In this paper, we will use the GloMoSim package to simulate the impact of the MANET density (increasing number of nodes) using the SNR-based VBS election algorithm on decreasing the "Packet Loss Ratio", and therefore increasing the "Packet Delivery Ratio" which is a significant parameter to be guaranteed to achieve QoS provisioning in MANET.

We will use the free space GloMoSim propagation model to predict received *signal strength* when the transmitter and receiver have a clear, unobstructed line-of-sight between them. This model predicts that transmission power is attenuated in proportion to the square of the distance. According to this model, the *Free Space Equation* for non-isotropic antennas is the following formula (8):

$$P_r = P_t \left(\frac{\lambda}{4\pi d}\right)^n G_t G_r \qquad (8)$$

Where P_r is the received power, P_t is the transmitted power (in Watts or milli-Watts), λ is the carrier wavelength (in meters), d is the distance between transmitter and receiver (in meters), n is the path loss coefficient, G_t is the antenna Gain at the transmitter and G_r is the antenna Gain at the receiver. For the Ideal Isotropic Antenna, the free space loss equation is given by the following formula (9):

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2} \qquad (9)$$

Where c is the speed of light and f is the frequency (in hertz).

4.4.1 Configuration parameters

The main input configuration parameters are specified in the configuration input file "config.in", to set the necessary input parameters, select the routing protocol (SNR-VBS in this simulation), the MAC layer protocol, the transport protocol, and the application (e.g. Telnet, FTP). The following script is an example of an input configuration file parameters:

```
SIMULATION-TIME              15M  //in minutes
SEED                         1
//random initialization seed number
TERRAIN-DIMENSIONS           (200, 200) //in meter
NUMBER-OF-NODES              100
//we modify this number to reflect network density
NODE-PLACEMENT               RANDOM
PROPAGATION-LIMIT            -111.0 // signals below
this parameter (in dBm decibel meter) are not delivered
PROPAGATION-PATHLOSS         FREE-SPACE
NOISE-FIGURE                 10.0
TEMPERATURE                  290.0//in K
RADIO-TYPE                   RADIO-ACCNOISE
RADIO-FREQUENCY              2.4e9//in Hz
RADIO-BANDWIDTH              2000000//in
bps(2MHz)
RADIO-RX-TYPE                SNR-BOUNDED
RADIO-RX-SNR-THRESHOLD       10.0      //in dB  we
modify this number to reflect and test different thresholds
RADIO-TX-POWER               15.0//in dBm
RADIO-ANTENNA-GAIN           0.0 // in dB
RADIO-RX-SENSITIVITY         -91.0 // in dB
(sensitivity of the radio transmission)
RADIO-RX-THRESHOLD           -81.0 //in dBm
(minimum power for received packet)
MAC-PROTOCOL                 802.11
NETWORK-PROTOCOL             IP
NETWORK-OUTPUT-QUEUE-SIZE-PER-PRIORITY        100
#ROUTING-PROTOCOL            SNR-VBS // proposed
protocol under development for an enhanced version
ROUTING-PROTOCOL             WRP // wireless routing
protocol predefined by glomosim package
APP-CONFIG-FILE              .\app.conf //
application configuration file
APPLICATION-STATISTICS       YES
ROUTING-STATISTICS           YES
NETWORK-LAYER-STATISTICS     YES
MOBILITY-TRACE-FILE          ./mobility.in
In order to configure the Mobility parameters, the
individual movements of the nodes will be taken from a
specified file: "mobility. in".
MOBILITY-POSITION-GRANULARITY  0.5
```

Figure 4. example of input parameters to be an input file.

4.4.2 Simulation Results Analysis

It is possible according to [11] to use the GloMoSim to get parameters such as: Packet Delivery Ratio, Percentage of Loss Rate compared to the total number of packets sent by the sources.

We used the WRP "Wireless Routing Protocol" defined by [13] to be a baseline for our simulation. We can see the impact of network's density (increasing number of nodes) on the percentage of Packet Loss represented by the following graph figure.

Using the WRP, we can notice from the resulted graph that for small number of nodes, it maintains also a low packet loss ratio. But, by increasing number of nodes in the network, the packet loss ratio also increases dramatically.

On the other hand, using the SNR-Based VBS routing protocol, we can note that for small number of nodes, it can achieve a higher packet loss ratio compared to the WRP. As the network density increases, it can maintain a relatively lower "packet loss ratio"

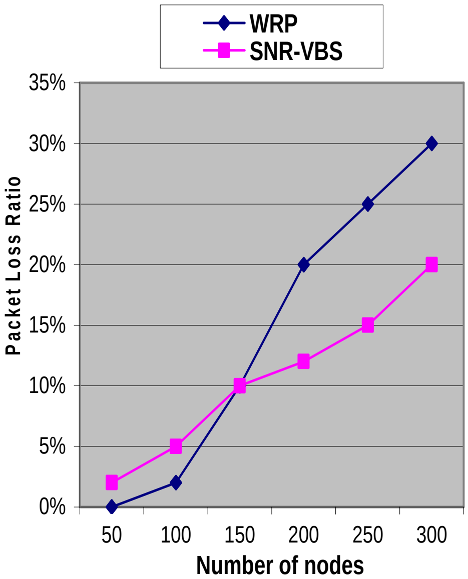

Figure 6. Impact of network density on packet loss ratio.

5. Conclusion and future work

In this paper, we proposed Virtual Base Station VBS election algorithm based on the Signal to Noise Ratio SNR to establish a promising QoS framework in Mobile Ad-hoc wireless Networks MANET.

The previous work in VBS and Power-Aware PA-VBS techniques has been a good guide and reference for this research. However, the future work should be considering more the real-world wireless network environment that suffers from limited available resources and high mobility of the users which makes the proposed algorithms necessary to be developed, tested and implemented.

Our future work is to enhance the proposed algorithm:"SNR-VBS" at different "SNR Thresholds" compared to the "PA-VBS" for a promising QoS framework establishment.

References

[1] C. Siva Ram Murthy, B.S. Manoj, "Ad-Hoc Wireless Networks architectures and protocols", fifth edition, Prentice Hall, 2004.

[2] Ahmed Safwat, Hossam Hassanein, Hussein Mouftah, "Power-aware virtual base station for wireless mobile ad-hoc communications, Elsevier Science, published 2002." www.elsevier.com/locate/comnet

[3] Shigang chen, Klara Nahrestdt, "Distributed Quality of Service routing in Ad-hoc Networks, IEEE journal on selected areas in communications

[4] Alaa Muqattash, Marwan Krunz, and Sung-Ju Lee, "A perspective on the design of power control for mobile Ad-Hoc networks", Wiley-IEEE Mobile wireless and sensor networks technology applications and future directions, May 2005.

[5] A. J. Goldsmith and S. Wicker, "Design challenges for energy-constrained ad-hoc wireless networks" IEEE Wireless Communications, August 2002.

[6] J. Luo and N.K. Jha, "Battery-aware static scheduling for distributed real time embedded systems", IEEE June 2001.

[7] P. Rong and M. Pedram, "Battery-aware power management based on Markovian decision processes", November 2002

[8] R. Zheng, J.C. Hou, and L.Sha, "Asynchronous wakeup for Ad-Hoc networks." Proceedings of ACM MOBIHOC June 2003.

[9] Mehran Abolhassan, Taedeusz wysocki ,Eric Dutkiewicz, " A review of routing protocols for ad-hoc networks." , www.ElsevierComputerScience.com/locate/adhoc, ad-hoc networks 2004.

[10] Lei Chen and Wendi Heinzelman, "Network Architecture to support QoS in Mobile Ad-hoc Networks." In Technical report of University of Rochester, NY 14627,2004, "{Chenlei,wheinzel}@ece.rochester.edu"

[11] Amis AD, Prakash R, Vuong THP, Huynh DT, "Max-Min d-cluster formation in wireless ad-hoc networks." IEEE INFOCOM, March 2000.

[12] Jorge Nuevo, "A comprehensible GloMoSim Tutorial.", INRS –Technical report of University du Quebec, March 4, 2004, "Nuevo@inrs-telecom.uquebec.ca".

[13] Shree Murth and J.J. Garcia-Luna-Aceves, "An efficient routing protocol for wireless networks", "Mobile Networks and Applications.",1996.

[14] GloMoSim: Global Mobile Information Systems Simulation Library. http://pcl.cs.ucla.edu/projects/glomosim