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Research Article

Simulated Comparison of Power-Aware Routing Protocols in Mobile Ad Hoc Networks

Gatete Marcel[1*], Harubwira Flaubert[2]

[1,2]Dept. Business Information Technology, University of Tourism, Technology, and Business Studies, Kigali, Rwanda

**Corresponding Author: mgatete@utb.ac.rw*

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Abstract— An infrastructure-less wireless network, or mobile ad hoc network (MANET), is one in which the topology is dynamically established in the absence of a central authority like a router, access point, etc. Due to the short battery life of its mobile nodes, which are powered by batteries, a node's active state is shortened by unplanned shutdowns or restarts. A difficult task in MANETs is extending the battery life of each node. This is achieved by creating and implementing a power-aware routing protocol that considers power optimization techniques—a method that is rarely used with native routing protocols. The reactive routing protocol MMBCR and the proactive routing protocol MBCR are two native routing protocols that are available in MANETs. In this work, their respective performances are evaluated. To demonstrate how using a power-aware routing protocol might improve MANET operating performance, an evaluation is carried out by contrasting these two protocols with a well-known power-aware routing protocol that is available for MANET MTPR. For assessing performance, four widely-used routing metrics are employed: the total number of missed packets, the end-to-end packet delivery ratio, the end-to-end delay, and the network lifetime. The simulation findings, conducted for all situations examined using the ns -2 simulator, verify that MTPR performs better than other protocols, MBCR performs mediocrely, and MMBCR almost performs worse than other protocols.

Keywords— MANETs, Performance analysis , Power-aware routing protocols, Routing Metrics, and Simulation.

1. Introduction

Ad-hoc networks [1] are easily set up because they have a self-organizing structure. On the other hand, mobile ad-hoc networks [2] are a particular kind of ad-hoc networking that is the most widely used wireless network because it can increase flexibility and is very easy to set up because nodes can join and leave the network at will, creating a dynamic topology. Ad hoc networks have several difficulties in their overall operations. One of the most common issues with MANETs is battery restrictions, which result from a restricted battery's lifespan that causes individual nodes to abruptly terminate. Energy management is required to fill this gap by extending and maintaining network connectivity, which reduces packet drops and end-to-end delays and raises the ratio of packet delivery to destination.

This method extends a node's lifetime by managing battery discharge, modifying transmission power, and scheduling power sources; power-aware protocols are created to achieve this goal. The purpose of this study is to assess the benefits of routing with consideration for network longevity. We achieve this by evaluating the performance of three different power-aware routing protocols: Minimum Total Transmission Power (MTPR) [1], Minimum Battery Cost Routing (MBCR) [2], and Mini-Max Battery Cost Routing (MMBCR) [3]. This paper consists of the following sections: Section II presents Related Work. The Routing Protocol overview is provided in Section III. We described the experiments and techniques used to compare the protocols in section IV. Section V presents the findings and discussions, while Section VI addresses the conclusion.

2. Related Work

Batteries power nodes in multi-hop wireless mobile ad hoc networks. Every time a node transmits data to another node, battery life is reduced. Therefore, a mobile node in an ad hoc network uses electricity when it is connected to the network or when it is idle. Thus, increasing battery life while preserving transmission power or batteries has become a difficult task. Thus, it seeks an improved routing system that gives greater attention to ad hoc networks.

Many researchers have created a variety of routing protocols to meet this difficulty. Every protocol has centered on optimizing mobile nodes' energy usage from various angles. It, therefore, seeks an improved routing system that simultaneously takes into account more ad hoc network scenarios. Improved routing protocols extend the life of networks, expedite data transfer between mobile nodes, and take node energy limitations into account.

Research on routing in MANETs has been ongoing, and many protocols have been developed recently to address routing-related issues. Simply said, power-aware routing protocols are modifications of the existing ad hoc protocols, such as Ad-hoc On-demand Distance Vector Routing Protocol (AODV), TORA, and Dynamic Source Routing Protocol (MMBCR). Power-aware routing protocols come in many different forms, including Minimum Total Power Routing Protocol [1], Minimum Battery Cost Routing Protocol [3], and Power Aware Source Routing Protocol [5]. Mobile nodes' battery power is maximized through the usage of these power routing protocols.

In some research such as [7] to provide high reliability, the authors defined the (L-POR) Link and Position-based Opportunistic Routing protocol. As traditional routing protocols are stateful routing protocols; this leads to communication, memory, and processing overheads. This protocol is a combination of geographic and opportunistic routing algorithms. First of all, it identifies the best forwarder node, the one with high power and link quality, and selects a candidate node for each forwarder node. Forwarder nodes forward the routing information to every neighbor, if the forwarder node leads to a failure condition at that time, the candidate node will take its responsibility and act in its place by effectively handling communication hole problems; to achieve this, the backup schemes were introduced. The candidate node will be selected based on which one has the minimum distance to the forwarder node; this results in eavesdropping minimization.

In [8], a power-aware multicasting mechanism was proposed aiming at reducing both the power consumed during the packets' transmissions and the end-to-end delay ratio while maintaining the minimum energy consumption; those network parameters were used for the multicast tree. The NP-complete, which is a QoS multicast routing problem was solved by the energy-efficient genetic algorithm presented in this paper. This study was limited to the source-based routing tree, the outcomes of the simulation proved that the proposed protocol was effective and efficient.

Authors in [9] discuss some useful algorithms that are efficient in managing the power consumed by the network traffic to provide a high QoS in MANETs. To achieve this, a lower energy consumption is required for a link between two different nodes during a unit transmission of the message. They assume that during the multicasting processes only a unit message is transferred. To reduce the packet's overflow, the MDPD-k scheduling algorithm which is efficient in effectively handling the packet scheduling operations was used.

Authors in [10] proposed a power-aware routing algorithm (PARA) for WMNs, which selects optimal paths to send packets, mainly based on the power level of the next node along the path. This algorithm was implemented and tested in a proven simulator. The analytic results showed that the proposed power node-type aware routing algorithm metric can improve the network performance by reducing the network overheads and maintaining a high delivery ratio with low latency.

3. Routing Protocols for MANET

3.1. Overview of routing protocols

To distribute packets from source to destination, numerous routing protocols have been developed and put into use. Table-driven (pro-active), on-demand (reactive), and hybrid routing protocols are the three categories of routing protocols that we identify in MANET [3]. Instead of creating routes to destination nodes on-demand like an on-demand routing protocol does, a proactive routing protocol keeps topological information in the form of a routing table at each participating node in the network, keeping paths between all nodes in the networks. The best aspects of proactive and reactive routing protocols are combined in hybrid routing protocols, as the name implies.

3.2. Power-aware routing protocols

Because of the low capacity of the batteries that power mobile nodes in MANETs for the entirety of their active period, these nodes are limited in power. While many routing protocols are effective at routing, they often ignore problems with node and network longevity, which can lead to early node termination and negatively impact network performance as a whole. To limit this issue, power-aware routing methods [1] are either proactive or reactive protocols that lower the amount of energy used during packet processing, including during transmission; To achieve this, they consider power management concerns to prolong the lifetime of both the node and the network as a whole. One example of such a protocol is MTPR.

3.3. Protocols description

3.3.1 The Minimum Total Transmission Power (MTPR)

The Minimum Total Transmission Power (MTPR) algorithm as described in [1], selects a path with the lowest possible total transmission power. Any node that needs a way to get to a far-off node will broadcast RREQ to all of its neighbors. This procedure keeps going at all intermediate nodes until the packet reaches its destination node. Although it chooses the path with the least amount of overall transmission power, the destination node receives RREQs from different nodes. Because of the inverse relationship between transmission power and distance. As a result, this technique chooses the greatest number of hopes to increase the distance.

Algorithm:
1. Determine the total transmission power for each network route.
2. Out of all the routes, choose the one with the lowest total transmission power.

3.3.2 Minimum Battery Cost Routing (MBCR)

Nodes are kept from being overused by MBCR [3]. The battery cost function, which is inversely proportional to battery capacity, is utilized in MBCR. The value of the cost function rises as battery capacity falls. Consequently, nodes with low battery capacities may still be chosen for transmission. It will choose a shorter hop path if all nodes have comparable battery capacities.

Algorithm:
1. Compute the total cost of batteries for any route that goes from one place to another.
2. Of all the transmission routes, choose the one with the lowest overall cost.

3.3.3 Mini-Max Battery Cost Routing (MMBCR)

MMBCR [4][5] gets around the restriction of MBCR's remaining battery capacity. The node is handled equitably. Larger battery-capable nodes are selected for transmission, whereas those with smaller residual battery capacities are avoided. The battery cost that is highest across all route nodes is chosen by this technique, as opposed to adding up the battery cost functions of each node on each specific route.
Algorithm:

1. Choose the battery cost function for each route that has the highest value among all of the route's nodes.
2. Of all the routes, choose the one that uses the least amount of battery now.

4. Experimental Method/Procedure/Design

4.1. Network metrics

4.1.1. Dropped packets fraction

The total number of packets lost during the simulation is known as the dropped packets fraction. The protocol performs better when the packet loss value is smaller. There are more dropped packets when there is an increase in network traffic. To make sure that these dropped packets are correctly transported from source to destination, packet retransmission techniques are employed. A large percentage of dropped packets has a major impact on the network's performance. The performance of the network is greatly impacted when the percentage of dropped packets is large. Numerous circumstances can also lead to packet loss, including link failure and broken links caused by node shutdowns or restarts, which can be brought on by low battery power. If a broken connection is an intermediate path on the route to the destination, it can result in irreversible packet drops [7].
Dropped packets fraction = Number of packets sent – Number of packets received

4.1.2. End-to-end delay fraction

A packet's average time required to reach its destination is known as the end-to-end delay ratio. There are numerous potential causes for it, including the router discovery cycle and the queuing mechanism employed in data packet transfer. Only packets of data that have reached their intended destination are included in the count. The protocol's performance is gauged by the end-to-end delay value; a lower ratio indicates a higher level of performance [8].

End-to-end delay ratio=∑ (packet-arrive time – packet-sendtime) / ∑ Number of connections

4.1.3. Packet delivery ratio

The ratio of delivered data packets to their destination is known as the packet delivery ratio. The packet delivery level is shown by this fraction. A higher number for the packet delivery ratio indicates better protocol performance.
Packet delivery fraction∑ = Number of received packets / ∑ Number of sent packets.

4.1.4. Network Lifetime

The entire period from the beginning of the network's operational condition to its complete inactivity is known as its network lifetime. However, the determination of when a system is deemed nonfunctional varies depending on the application. Numerous things can lead to it, such as mobile node failure, network splits, a reduction in coverage overall, etc. The network's performance is negatively impacted by these issues. Increasing the battery's power is one way to solve these issues [9].

4.2 Simulation Model

NS-2 is a discrete event simulator targeted at networking research. It provides substantial support for the simulation of routing and multicast protocols over wired and wireless networks. It consists of two simulation tools. It contains all commonly used IP protocols. The network animator (nam) is used to visualize the simulations.

We used two NS-2's key languages: C++ and Object-oriented Tool Command Language (OTcl); while C++ defines the internal mechanism (i.e., a back-end) of the simulation objects, the OTcl sets up simulation by assembling and configuring the objects as well as scheduling discrete events (i.e., a front-end). After simulation, we output animation-based simulation results. To interpret these results graphically and interactively, NAM and XGraph were used. The result of the simulations is an output trace file that was used to perform data processing (calculate delay, throughput, etc.) using the AWK tool which was also used for data extraction, and reporting.

4.2. Parameter values

Table 1. Network parameters

Parameter	Values
Number of nodes	120
Interface type	Phy/WireLowPhy
Channel	WireLow Channel
Mac type	Mac/802_11
Queue type	Queue/DropTail/PriQueue
Queue length	150 Packets
Antenna type	Omni Antenna
Propagation type	TwoWayGround
Size of packet	512-1024

Protocol	MTPR, MBCR, MMBCR
Traffic	CBR
Simulation area	1500M*1500M
Node mobility speed	1…50 m/s

As presented in Table 1, a network size of 120 nodes is created for our performance evaluation. Each node randomly moves with a speed ranging from 1 to 50 m/sec in a simulation area of 1500*1500M with a transmission range of 250m, the overall simulation time is set to 200 secs.

The traffic management operations are performed using a Constant Bit Rate (CBR) with a generation rate of 100 kb/s. Each data packet's size ranges from 512 to 1024 bytes. IEEE 802.11 for wireless LANs is used at the MAC layer with a radio propagation model of Two-Ray Ground. The pause time is regularly taken after 10 seconds. Queue type is set to Queue/DropTail/PriQueue and length to 150 packets.

5. Results and Discussion

5.1. Dropped Packets Ratio

Figure 1 illustrates how the packet drop ratio for each of the three protocols rises in direct proportion to the number of mobile nodes when the number of nodes varies. Because it can maintain the power in each node's battery, the MTPR protocol performs better than other protocols for the overall simulation time. This is because fewer packets are dropped, which can be caused by an intermediate node shutting down due to low battery power, which then prevents the route to the destination from being available. The MBCR performs poorly in every scenario; as the number of participating nodes rises, it gets worse and maintains a nearly constant dropped packet percentage. MMBCR keeps the simulation time average during the whole simulation.

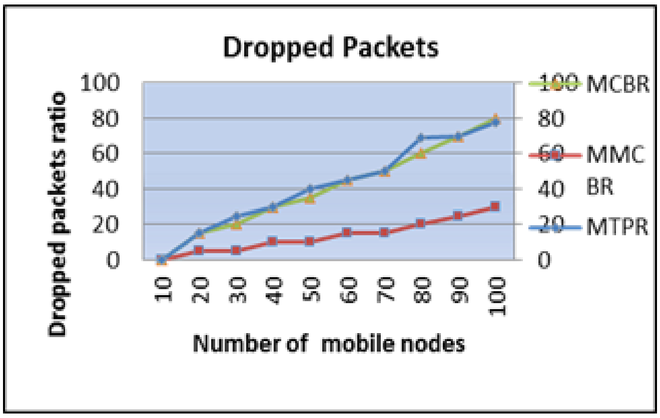

Figure 1. Number of nodes vs dropped packets ratio

5.2. End-to-end Delay

When there are fewer than 20 mobile nodes, all three protocols perform almost at the same level. However, when the number of nodes rises above 20, MMBCR performs worse than the other protocols consistently due to network overhead and power consumption, which rises proportionately with the number of nodes. Figure 2 illustrates this phenomenon. Once again, EPA R performs better than the other protocols because its average end-to-end delay level is always lower than those of the other protocols. However, when the capacity of the network increases, both MMBCR and MBCR maintain a gradually growing end-to-end delay level. Finally, it's interesting to note that the end-to-end delay ratio grows proportionally with network size for all protocols.

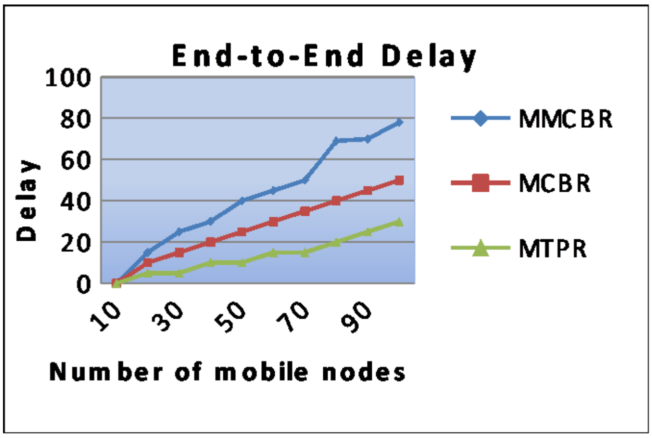

Figure 2. Number of mobile nodes vs end-to-end delay

5.3 Packet Delivery Ratio

Regarding the packet delivery ratio, Figure 3 illustrates the shortcomings of the MMBCR protocol in comparison to MTPR and MBCR. Specifically, for small, medium, and large nodes, it maintains a low packet delivery fraction that varies little as the number of nodes rises. The large amount of missed packets and increased end-to-end latency of MBCR are caused by the network's inability to sustain a high level of battery power on nodes while its size dynamically grows, rendering many nodes unavailable. Once more, MTPR has improved performance because it keeps a high packet delivery ratio, which makes it a superior protocol for end-to-end packet delivery. The performance of all three protocols is the same when the number of nodes varies from 1 to 10, with the packet delivery ratio for MBCR remaining nearly constant and beginning to rise in direct proportion to the number of nodes while the other two protocols perform similarly.

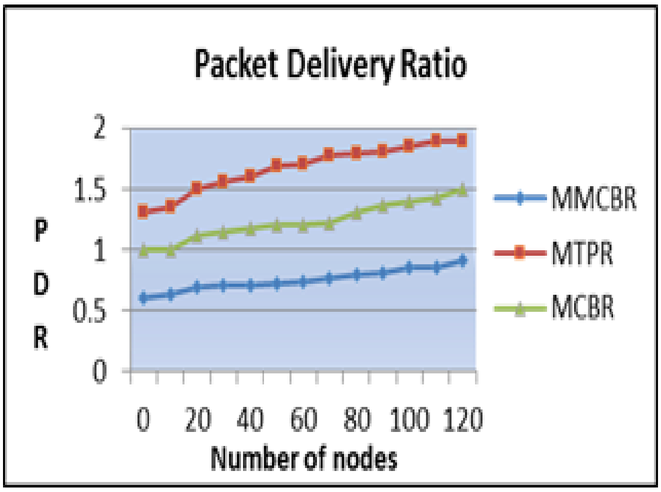

Figure 3. Number of mobile nodes vs end-to-end Packet Delivery Ratio

5.4. Network Lifetime

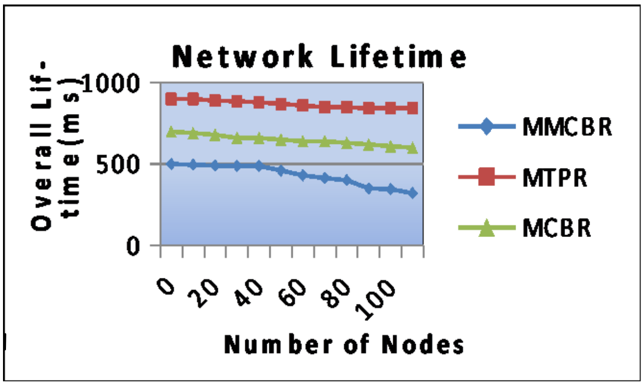

Figure 4. Number of Nodes vs Network Lifetime

The network lifespan, an intriguing metric that illustrates the combined effectiveness of all three procedures, is displayed in Figure 4. Once more, EPA R is a superior protocol since it handles end-to-end delivery while accounting for energy concerns. This minimizes the number of mobile nodes that would otherwise have to be shut down or restarted owing to low battery power, extending the network's lifespan. Another finding is that, by operating at a moderate level, MBCR beats MMBCR. The network lifetime gradually declines for all three protocols, in direct proportion to the number of nodes. This is because increased network density causes dropped packet and end-to-end delay ratios to increase, which in turn affects the performance of the network as a whole.

6. Conclusion and Future Scope

This study compares the performance of three efficient protocols in MANET— MBCR, MMBCR, and MTPR, the most widely used power-aware MANET routing protocol. These three protocols did not show any appreciable differences for the tiny networks. MTPR works better than other protocols for medium- and large-scale MANETs because it can sustain high battery power levels for extended periods. This demonstrates the need to consider energy-related concerns while routing. This demonstrates the need to consider energy-related concerns while routing. In contrast, MBCR performs mediocrely in terms of total network lifetime, packet end-to-end delivery, and end-to-end delay. However, it performs worse in terms of dropped packet percentage since the quantity of lost packets increases in direct proportion to the number of mobile nodes. Overall, the results demonstrate that MMBCR nearly always performs worse than other protocols in all scenarios examined, except medium performance for small, medium, and large networks when performance evaluation is done using the dropped packets parameter. All of these findings demonstrated how crucial it is to consider power consumption strategies when routing since low battery power resulting from some routing protocols' ineffective power management causes unexpected node shutdowns and restarts, which limits a network's overall performance. To address this, we suggest considering power management when developing an effective routing protocol.

Conflict of Interest
The authors of this research study do not have any conflict of interest.

Authors' Contributions
Author 1 was involved in protocol and algorithm development, gaining ethical approval, simulation study, and data analysis.

Author 2 Researched literature and conceived the study and wrote the first draft of the manuscript.

All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Recommendations
After analysis and interpretation of the data, the researcher came up with the following recommendations:

- First, few robust standard power-aware routing protocols for multimedia applications exist in the literature, a more deep research should be done in this field about the transmission of any kind of data.
- Second, our proposed scheme can be extended by deeply taking into account multi-path routing to avoid interference during the transmission.
- Third, future researchers should deal with improving the network lifetime and stability in MANETs with speedy nodes by predicting the future direction of the mobile nodes.

Finally, the experimental evaluation of our model in a real testbed, including indoor, outdoor, and mobile nodes would give more insights into the prediction capacity of our model in a larger set of

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AUTHORS PROFILE

GATETE Marcel holds a Doctor of Philosophy degree from Periyar Maniammai University, India 2012-2018, Master of Philosophy PRIST University, India 2010-2011, M.SC. Bharathidasan University, India 2008-2010, B.SC., Institutut Superieur Pedagogique de Gitwe, Rwanda 2002-2006. He is currently a Senior Lecturer in the Department of Business and Information Technology at UTB (University of Tourism, Technology and Business Studies, Kigali Rwanda since 2021. **Interested Area:** Mobile Ad Hoc Networks and Computer Programming.

HARUBWIRA Flaubert- Holds a Master's in Information Technology, University of Bharathidasan, Bishop Heber College, India 2011-2013, Master's in M.com Banking and Insurance Management, Annamalai University, India 2012-2013.; University of Gitwe, Bachelor of Computer Engineering Rwanda 2003- 2007. Dean of the Faculty of Business and Information Technology in UTB (University of Tourism, Technology and Business Studies, Kigali Rwanda from 2021 till date. Interested Area: Networking.

