# Power-saving Routing Algorithms in Wireless Mesh Networks: a Survey

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**Abstract**

In Wireless Mesh Networks, nodes often have a limited battery supply to use for the sending and reception of transmissions. By allowing nodes to relay messages for other nodes, the distance that needs to be bridged can be reduced, thus limiting the energy needed for a transmission. However, the number of transmissions a node needs to perform increases costing more energy. Power-aware routing refers to the mechanism of taking into account the remaining battery capacity of the node in order to decide on whether or not to relay traffic. The usage of nodes having low capacity should be avoided for relaying traffic. Efficient routing algorithm is used to find out cheapest route ie, based on number of hops within a mesh network. This refers to high load on some nodes, that in turn refer to uneven battery discharge over the nodes. So power aware routing is based on the amount of battery a node is having. In this paper, we present the related works on lowest consumption of energy, Tools used to simulate, we provide a comparative analysis. Finally we present the challenges in power-save routing algorithms in Wireless Mesh Networks.

**Index Terms:** Power-save, Routing, Wireless Mesh Networks,

## I. Introduction

Wireless Mesh Networks (WMN) can be seen as a basis for creating the architecture due to their decentralized nature, easy and fast deployment, inexpensiveness and reliability. No centralized Access Point is required and alternative routes can be used if one Mesh Point in the network fails. Since Mesh Points are small battrey powered devices with limited energy capacity, energy consumption is one of the most critical technical problems to be solved.

A WMN shown in Fig. 1, typically consists of Networks of access points which are connected through a wireless backbone. Due to rapid growth and deployment of such networks, research focus has shifted to finding ways to minimize the power consumption of these networks. This reduction in power consumption is important from operator's view because it directly impact the cost of operating the network. Several works show how power consumptions can be reduced by avoiding long range communication in favor of multihop transmissions. Since routing is an essential function of such multihop networks, a lot of research effort has been made in recent years to design power aware routing algorithms.

The main effectiveness of routing technique is to increase in bandwidth which internally related to energy consumption at network level. Power consumption by network field is the major dealing problem faced up in the current technical world. Some important reasons for this problem can arise in hundreds of ways due to improper

network design, routing problem and so on. This type of problems are mainly related to communication and computaion. Identifying and providing solutions to such troubles are the tremendous challenges to the existing proficient domain.

In this paper we compare various situations of power save routing either technically or mathematically. Different approches related to power save routings are discussed and campared to identify the challenges and scope for research work.

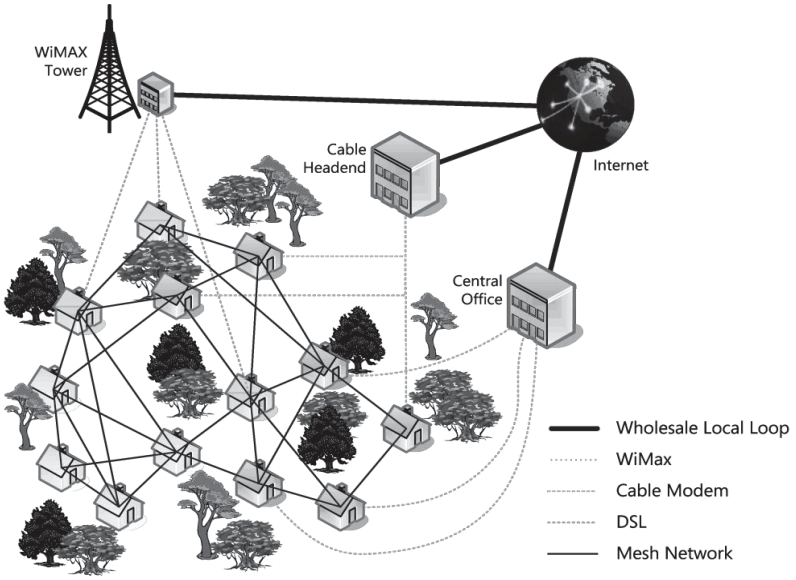


Fig. 1. Wireless Mesh Network

The rest of the paper is organized as follows: Section II discusses about the classification of power save routing algorithms. Section III unfolds the related work carried out. Section IV presents the tools used to simulte the models. Section V describes the compartive analysis. Section VI discusses about the challenges and scope for work and conclusion is given in Section VII.

## II. CLASSIFICATION OF POWER-SAVE ROUTING

Serveral approches as been made to reduce the energy consumption at the network level. This section provides a classification diagram which reveals different ways available to reduce the energy consumption. Power save routing can be divided into five main classes as shown in Fig.2.

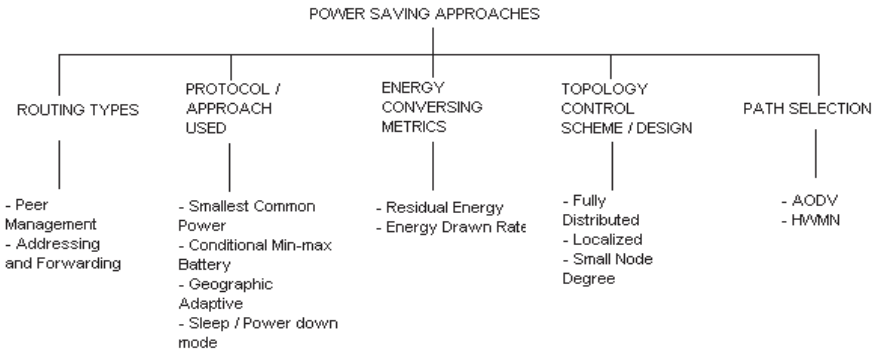


Fig.2. Power save rouging diagram

## III. Related works

In this section we describe different approaches used for power-save routing. The various classification made to reduce power consumption is depicted in Fig. 2. The power save approaches are affected by the following main aspects:

**ROUTING:** Routing depends on the effective and efficient decision making. In general routing can be made in two ways.

1. Peer management: In peer management, there will be processes running in two processors in Mesh. The routing is done to get the respective path for transfer of data for the exact host in network in which the process is running and here the constraint arises is the mesh station which is allowed to transmit only when the peer link is established. Also, this guarantees that the information transferred will be reliable.
2. Addressing and forwarding: In addressing and forwarding technique, there will not be any specific request for any node of WMN. When the request comes from intermediate hops, the sender sends information based on address and then forwards to next intermediate node. There will not be any specific rules like; the information must pass through some particular nodes etc. Here, usually two nodes at source acts as transmitters and two more nodes at destination acts as receivers [1]. There will be some addressing method to address these nodes called four-way addressing [3]. If the information or frames has to be transferred outside the mesh network, it requires two additional addresses. This is known as six-way routing.

**PROTOCOLS:** The protocols will also affect a lot in energy consumption if the service is reliable. The energy consumption will be more because of reserved routing path irrespective of transmission through network. By considering these factors, the protocols are classified into four main sections:

**Smallest common power protocol:** This protocol provides two way communications to all hops/nodes of mesh network. All nodes will be at same transmission level called Pi. If Pi is low, one hop can communicate to only limited number of hops or nodes in mesh network. If Pi value is too high, then the node in mesh network can communicate to any node, without the needing of intermediate nodes. But energy consumption will be more. So energy consumption is decided by the value or factor Pi.

**Conditional max min battery capacity routing protocol:** In this protocol, the route path will be selected based on the threshold required by individual node or the minimum battery on each node to transmit frame via same route. If a node has more threshold than required, then power route path will be selected, else the max min path will be selected which goes with less energy consumption.

**Geographic adaptive fidelity protocol:** Here each node with its GPS will be converted into a virtual grid. So the entire area will be divided into many number of grids and the one with more battery capacity will become the master of grid, it's all information will be kept in routing table. The slave nodes will switch between on and off by making sure that master node will be awake or will have battery all the time.

**Sleep / power down mode:** Here, the nodes used to sleep to avoid the more energy consumption. The radio consumes more energy. So it will be kept off when the node sleeps. But when all nodes slept, there will not be any data transfer at all. So the master node will be awake and the rests slaves can sleep to save energy.

The protocols are used to discover multi hop paths and used to maintain them. Few path selection techniques are used to select best path among the various paths available. The general way of implementing any network is using general routing methods and default path selection techniques to ensure minimum interoperability between the devices from different vendors [3]. So always the same path will be used for transmission. This method is defined in HWMP-hybrid Wireless Mesh Network protocol. HWMP technique is inspired by AODV tree routing. HWMP enables reactive and proactive ways for implementation and selection of best paths. Also by selecting multiple paths, instead of default path, we can save energy. The path has to be selected based on less substantial. This saves the energy at different nodes [1]. For saving power to still more extent, processing and sleep algorithms has to be efficiently implemented. The transmission power control technique is used for more efficient transmission with less energy consumption in AODV networks [2].

**ENERGY CONSERVING METRICS:**

The main factors to get the energy conserved by routing protocols [5] are categorized into two types:

**Residual energy:** The energy consumption is the very main factor of routing. To get rid of energy starvation by route selection, the min-max battery capacity routing is used. The idea is the shortest path will be used for some time till some energy is consumed before choosing the algorithms for routing.

**Energy drain rate:** It defines the rate at which the energy being consumed. The traffic passing through a node will be deviated to avoid the hops or nodes failure because of battery discharged, or when the lifetime of battery gets over. A special method called exponential weighted average method is used to calculate the energy consumed. This gives approximation amount of energy being consumed by any node.

**TOPOLOGY CONTROL SCHEME/DESIGN:**

Even though the Mesh Networks are stationary in nature, it is difficult to maintain the connection because of transient nature of wireless links. The topologies in which the nodes are arranged also matters in power consumption and network capacity. In ad-hoc networks to avoid energy consumption, different approaches are used in [6]. The connection maintenance task is important in any networks topology control scheme. Two kinds of approaches are used, CTR-critical transmission range and CNN-critical neighbor number.

In CNN, the minimum number of nodes must be connected to a node as neighbors in order to keep network connected, only knowledge of network size is efficient for CNN [7]. This CNN affects heterogeneous transceiver power output which actually affects energy consumption and CNN is less affected by the position of network so we need not assume GPS (Global Position System) router, also it has quite good aspects and properties to save energy. The main properties are:

**Fully distributed:** The main base of Wireless Mesh Networks is, it is not centralized and distributed. So this helps in practical relevance of technical communication. Three types of information generation can be retrieved by technical communication: Local information, Direction information, Neighbor information. The device with low quality neighbor information will be found by routing table and then pro-active routing method will be used for consuming less energy.

**Small node degree:** In practical, it is very difficult to find the node degree - that is number of neighbors within the range. But we can easily determine the logical node

degree which can be done by calculating or finding the number of messages passed through a particular node. If reactive routing is used, then logical node degree calculation will get still easy.

**PATH SELECTION:**

Consider a network as shown in Fig. 3, the source node requires new and unique paths to reach destination with less energy consumption [3]. The source node will not select the nodes with less battery capacity even though the path is of less energy consumption. So this affects the network's life time. In the case of AODV, the transmission is on-demand. AODV is said to be baseline for all protocols [2]. It discovers the path whenever needed. So the frames will be sent only when there's a demand. So when there is a demand, source discovers path by sending a route request RREQ and when it reaches destination, it responds by route reply RREP assuming that the energy at all nodes is same, the maximum energy will be calculated by adding the energy at each nodes of RREP packets. Then these packets will be sent to source. When all packets are received, the destination checks which node is having highest energy and through that node, information will be sent to destination.

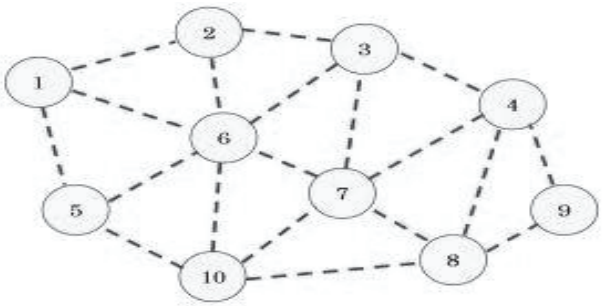


Fig. 3 Intermediate nodes

## IV. TOOLS USED TO SIMULATE

In this section we will discuss about different tools used to simulate the results in power save routing in Wireless Mesh Network.

**DTNsim2:** It is a DTN simulator written in java developed by soshin research group, university of waterloo. Ambit of this is to write simple scripts which allow configuration, contact schedules and traffic parameters to be in a file or in multiple files and also MEED routing protocol from practical routing in delay-tolerant network (DTN) paper, protocol stack architecture for modern newly routing protocols from sets of different agents. We extensive the DTNSim2 with an energy layer which is noticed for each node. The energy layer keeps track of nodes available battery capacity [5].

**NS2 Simulator:** NS2 Simulator addresses mainly on simulated objects. This is based on two languages either c++ or oTcl. First one is object oriented simulator written in C++ and second one is oTcl interpreter which is used to execute user command script where oTcl acts as a front end. This simulator affirms classes in C++ as well as similar classes in oTcl. Class hierarchy in C++ is called as compiled hierarchy and that of in Otcl is known as interpreted hierarchy. Network simulator uses languages because simulator has two kinds of things it needs to do [2]. System programming can efficiously control and manage bytes, packet headers, and implement algorithms that run over large datasets etc. These system programmings are obligatory for elaborated study of protocols. For these

chores run time speed important and turnaround time is less important. Looping times is important in case of networks researches which include intimacy of slightly varying parameters or configuration, or quickly dig into number of scenarios.

**NS-3 Simulator:** It is a discrete-event network simulator aimed at research and educational field. This is not an extension simulator of NS-2, instead it is a new simulator. It is written in c++ but does not support ns-2 API. NS-3 was designed and implemented from scratch to be easily extensible, maintainable and understandable. NS-3 is large and perplexed system.

## V. COMPARATIVE ANALYSIS

In this section we compare several power aware routing algorithms. We can conclude that the network life time depends on the active time or duration of network, before it's first node expires. The table 1 summarizes the comparison of different power save routing algorithms available against different parameters such as routing, types of network used and concentration on energy awareness.

TABLE I
COMPARISON OF DIFFEREENT POWER-SAVE ROUTING ALGORITHMS

| Routing Algorithms | Network | Routing | Energy | Routing Type |
|---|---|---|---|---|
| * AODV[2] | MANET | Yes | No | Reactive |
| + HWMP[8] | Mesh | Yes | No | Hybrid |
| # LPR[5] | Mesh | Yes | Yes | Proactive |
| @ MTE[3] | Any | Yes | Yes | Reactive |

* It is on-demand, discovers route only when they are needed. It incorporates distance vector routing protocol.

+ It is inspired by AODV and tree-routing, combination of both proactive and reactive routing protocol enables HWMP to efficient path selection.

# It is based on a routing metric, which utilizes the energy flow model along with node life time prediction.

@ It is routing protocol that selects the route with minimum transmission energy. Here nodes closest to source heavily used, so these nodes die quickly.

## VI. CHALLENGES AND SCOPE OF RESEARCH WORK

In this section we discuss about the challenges and scope for research work under power save routing algorithms.

**Challenges:**

- Wireless Mesh Network is self-formed and self–reconfiguring network that can be distributed at any time anywhere. For battery controlled nodes power preserving is a major intriguing matter. Since the type of node is dynamic the rate of data transmission is not taped or determined. In depth it means if the transmission is direct between two nodes, then the battery power required is more than that of having an intermediate node. Demanding task here is to reduce to the energy consumption and increase the life span of the Network.

- Traditional wireless communication is half-duplex. That is, the wireless device can either transmit or receive at a time. In a Wireless Mesh Network this poses great challenges. If node
    - A is forwarding data to node B on a channel, node B cannot transmit to node C on same channel because the medium will be sensed as busy by both nodes C and B. Also node C cannot communicate to node D on same channel. This can potentially reduce the available bandwidth to half at every forwarding node.
    - Obviously when there is low bandwidth for the transmission then the ENERGY consumed will be exponentially more.
- To overcome the above mentioned issue, we can have multiple channels work in a mesh where all devices have a single radio. This adds overhead on MAC, to select appropriate channel between node-pair to maximize bandwidth. This in turn requires more ENERGY for selecting the appropriate channel.
- As all the mesh devices can be mobile, if a mesh device situated in a data forwarding path, tries to move beyond the range of its neighbors, the link carrying the data through that path will be broken. The moving device may have some frames stored, that it was unable to forward. In this case, a mechanism is needed to forward these frames to its destination via a new forwarding path where the device has now moved to or through some default forwarding path. This mechanism adds a drawback in conserving the ENERGY resources.
- Suppose packet size is more than the amount of ENERGY required to transmit the required data is high.
- Energy aspect is concerned while the packet enters and leaves the queue as well as routers or nodes.
- Devices that are lying at the outer edge of a mesh or that are located far away from a Mesh Portal can potentially be in a disadvantageous position. As every single hop reduces the bandwidth, outer devices will take longer to reach the network and will experience performance degradation as there is no differentiation between traffic from different nodes. This performance degradation asks more ENERGY to recover.
- Network management also poses an ENERGY consumption challenge because of the mobile nature of mesh devices. Device failure can potentially go undetected because of the self-healing and self-organizing nature of the network. Thus in order to detect the failed device in the mesh a new algorithm is required which consumes ENERGY
- In 802.11s there is one mandatory protocol that has to be implemented. The standard also defines an optional protocol. The important routing protocols are:
    - Hybrid Wireless Mesh Protocol (HWMP)
    - Radio Aware Optimized link state routing protocol (RA-OLSR)

It is found by observation that these two protocols are the major power consumer in the whole system. But unfortunately these mandatory protocols cannot be removed even though they require more ENERGY to work properly.

So the main challenge in this research is in minimizing the power consumption level to a maximum extent by considering other parameters like size of data, delay, type of data, bandwidth available in the network etc.

## VII. CONCLUSION

In Wireless Mesh Network, Routing functions are used as highly predicting technique. To build a green mesh network, it is necessary to design efficient routing protocol. Authors of [1], [3], [5], and [6] have considered conventional graph theory pre-select set minimum path, the multi-hop mesh network which are referred from wired network protocol. In these protocols the links are denoted by edges and path is represented using sequence of edges. Speciality of wireless mesh networks compared to wired network is its broadcasting nature. That is, when the packet is broadcasted by a sender, then the same packet is received by all neighbours. This nature enhances the spatial diversity that has not been employed by many of routing protocols as a part of minimizing power consumption in wireless networks. The most important aspect to be considered is, In wireless network links are more unstable and unreliable or treacherous than wired links. This disadvantage of wireless links leads to poor end–to-end performance, retransmission of large number of packets, and frequently route to discover the correct path when the selected path is not identified for packet delivery.

Some emergent protocols have been proposed in order to defeat or overcome from the disadvantages of wireless links and utilize the broadcasting feature to an extreme range [4]. Routing protocols pre-select forwarding, candidates beforehand and the selection of an appropriate forwarder list is not frivolous especially for multiple source destination pairs in a large scale multi-hop wireless network. Moreover, in order to compute the forwarder list, a large number of control messages are required, which results in high energy consumption.

To deliver data and packets in a controlled manner, we have to generate and implement a scalable, opportunistic, and energy efficient routing protocol. So there is a potent requirement for achieving power saving methods in network level for wireless network's long life time.

We can observe that, current power-aware algorithm uses only "current knowledge" of a system. We can think of extending in terms of using a trend of each node power consumption like, the closest node in short time period will have extremely low energy because of it's very craggy power trend (for instance we have a number - derivative, which shows how fast node battery is loosing her power), the route can take it into account and send a packet through another node.

Also We can notice that there is no prominent mathematical model which suggest the need to change route during routing based on the low power battery status at the node. There are no algorithms which analyse some time series traffic parameters for trend extraction or change point detection or some prediction.

## REFERENCES

[1] Martin M. Mhlanga, Thpmas O. Olwal, "Energy Optimization based Path Selection Algorithm for IEEE 802.11s Wireless Mesh Networks", IEEE Africon-The Falls Resort and conference centre, Livingstone, Zambia, September 2011.

[2] Sasikumar P, Mathew Abraham Roy, "Analysis of Power Saving Routing Protocol for Wireless Mesh Networks", International Journal of Computer Applications, Vol. 12(2), page no. 16-22, December 2010.

[3] Inwhee Joe, "A Path Selection Algorithm with Energy Efficiency for wireless Sensor Networks", Fifth international conference on software engineering research, management and application, SERA, 2007.

[4] Soumya Dey, Himanshu Sarmah, "Energy Efficiency in Wireless Mesh Networks", IEEE International conference on Computational Intelligence and Computing Research(ICCIC), Dec 2010.

[5] Veljko Pejovic, Elizabeth Belding, Mahesh K. Marina, University of California, "An Energy Flow Model for Self-Powered Routers and its Application for Energy Aware Routing", ACM, 2009.

[6] P Mudali, T. C. Nyandeni, N. Ntlatlapa, “Design and implementation of a Topology Control Scheme for Wireless Mesh Networks”, IEEE conference AFRICON, 2009.
[7] Xiaofei Wang, Athanasios V. Vasilakos, Min Chen, Yunhao Liu, Ted Taekyoung kwon, “A Survey of Green Mobile Networks: Opportunities and Challenges”, Mobile Networks Applications, Volume 17, page no. 4-20,Springer science, 2011.
[8] Kirill Andreev, Pavel Boyko, “IEEE802.11s Mesh Networking NS-3 Model”, IITP, WNS3, March 2011.