

Hole Detection and Hole Healing in a Wireless Sensor Network using LeDiR Methodology

K. Rama Krishna* and K. R. R. Mohan Rao

Department of Electronics and Computer Engineering, KL University, Vijayawada, Andhra Pradesh, India; Kakkera. ramakrishna@gmail.com, Mohanrao5423@kluniversity.in

Abstract

Objective: To monitor and control the total area of a Wireless Sensor Network (WSN) without any coverage holes that impair the sensor node functionalities. **Methodology:** We propose an exhaustive arrangement, which operates in two phases, hole detection and hole healing. We design our system based on Least-Disruptive topology Repair (LeDiR) algorithm. LeDiR scheme enhances the conventional and the extant route discovery techniques in the network, easing the tasks of hole detection and hole healing. **Finding/Improvements:** We implement our system in NS-2. Our proposed system implements LeDiR, effectively controls the WSN of coverage holes and successful in implementing hole detection and hole healing. We also demonstrate that our scheme is successful in overcoming both the coverage holes and routing holes.

Keywords: AODV, Coverage Holes, Hole Detection, Hole Healing LeDiR, Mobile Networks, NS-2, Routing, Wireless Sensor Networks

1. Introduction

A WSN comprises of individual sensor nodes designed for gathering data from the area of observation and corresponding with one another by means of wireless handsets. The gathered information will be conveyed to one or more sinks, by means of multi-hop correspondence. The individual sensor nodes in general are anticipated that they would work with batteries and are regularly conveyed to unfriendly environments, in vast amounts. It can be cumbersome to recharge or substitute the batteries of the sensor nodes regularly. Then again, sensor sink is generally rich in power. As we can observe that the individual sensor node energy is the most valuable asset in a WSN, proficient use of the energy to extend the lifetime of the sensor network has been the primary part of the research and development in the field of WSN. The communication in WSN follows many-to-one property, in which information from numerous sensor nodes have a tendency to be packed into a fewer number of sensor sinks. Following multi-hop routing technology, far off sensor nodes from the sinks require to conserve larger amounts of energy,

the sensor nodes close to the sink can be loaded handling a huge amounts of traffic from different nodes.

Individual sensor nodes are seriously restricted in terms of energy, memory, low range correspondence, bandwidth, and processor speed and data transfer capacity. Constrained battery power is utilized to work the sensor hubs and is extremely hard to replace or revive it, when the node dies of exhaustion of the energy. This could influence the system execution speed and performance greatly. We can optimize the energy conservation by energy usage minimization and optimizing the communication range^{1,2}. Sensor nodes are deployed in the area of observation to accumulate data and usually expected that each and every one of the sensor nodes works persistently and transmit data to the maximum extent possible. This addresses the lifetime issue in WSN. Individual sensor nodes exhaust their energy by the processes viz., transmitting the information, receiving the packets and relaying those received packets if needed. Subsequently, designing a routing protocol that boosts the life time until the maiden battery lapses is a critical aspect. Planning energy

*Author for correspondence

aware routing protocols greatly expand the lifetime of individual sensor nodes^{3,4}.

In certain applications the system size is larger than the required scalable models. Energy conservation in WSN has been the essential goal of any routing protocol developer, yet, this particular constraint is by all accounts, not the only the constraint for effective functioning of WSN systems. There are various different objectives like versatile designing of an architecture, routing, quality of forwarding path and latency^{5,6}. In majority of the WSN applications, they are imagined to take care of the basic situations like, information recovery i.e., conveying data of every individual sensor node as quickly as possible, with a means of secure data sharing among the nodes, that could reasonably be expected to the base station turns out to be an important issue^{7,8}.

It is a crucial matter to guarantee that the data should be satisfyingly retrieved and received at the base station. In WSN data accumulation and routing are vital, troublesome and challenging activities because of their dynamic properties. Numerous routing techniques and protocols are designed, among those protocols developed cluster based routing techniques are energy effective, versatile and extend the system life⁹. In the event recognition physical environment sensor nodes become active only at the time of event recognition and stay idle for the most of the time. Individual sensor nodes send the accumulated data to the base station in a periodical manner. Routing is the critical issue in information gathering WSN, while sleep-wake synchronization is the critical issue for event detection WSN.

There are certain properties that are required to be satisfied when designing a protocol for a Wireless network, in other words, an ad-hoc routing protocols. We'll look into some of the desired properties of an ad-hoc network.

Distributed Operation: The protocol we're going to design ought to be distributed in operation. It ought not to be subjected to a central consolidated control node. This situation holds even for stationary network systems. The distinction is that the sensor nodes in an ad-hoc system can arrive or exit the system effectively and in view of mobility and portability the system can be distributed.

Loop Free: To enhance the comprehensive performance of the system, the routing protocol should look after the routes selected for data transmission are ensured in beforehand that they are loop free. This greatly reduces the unwanted usage of bandwidth or processor consumption

Demand Based Operation: To lower the control overhead and wastage of the resources in the system, the protocol we intended to work on the network ought to be reactive in nature and must not intermittently broadcast the control data.

Unidirectional Link Support: The connections built up in radio environments can be used to enhance the execution speed of the system greatly.

Security: Radio environments are inclined to impersonation assaults. With a specific end goal to guarantee the desired behaviour of the routing protocols that we've designed, efforts to establish safety and security parameters like verification, authentication and encryption via the publishing of keys among the sensor nodes in the ad hoc network system is a vital and equally challenging task.

Power Conservation: The sensor nodes in an ad-hoc system are naturally constrained in power and use standby mode to spare the energy. It is obvious that the routing protocols ought to incorporate sleep modes.

Multiple Routes: To lessen the effect of topological modifications and congestion, numerous paths can be utilized. On the off chance that a course we chose is inoperative or faulty, there might be an alternate route that assists in sparing the routing protocol from starting various other route discovering strategy.

Quality of Service (QoS): It is an arrangement of administration pre requisites that should be maintained by the system while transmitting a packet stream from a source terminal to its destination terminal. Its needs are administered by the administration prerequisites of end user or client applications and anticipated that would ensure an arrangement of certain quantities that clients regard end-to-end execution, for example, delay, transfer speed, packet loss probability, jitter, and so forth. Power utilization is another QoS property which is more particular to MANETs.

Existing works mainly concentrate on sensor hub arrangement and then after Hole-discovery works by a node within the reach of two-hop neighbours. Not all individual boundary nodes can be distinguished accurately by this method of operation. In this way, one of our essential inspirations is to permit the development of temporary development systems without any wires and no centralized authority required.

A multi-hop data exchange mechanism is a self-shaping, self-recuperating and self-getting arranged in a perfect world suited for such versatile frameworks which

exist in unpredictable and always showing signs of change situations¹⁰. Be as it may be, subsequent to each individual node in an ad-hoc system is in charge of sending/forwarding data packets to different sensor hubs in the network, any failure or abnormalities of an individual critical node can bring about a system partition. Thus it is desirable to have an ad-hoc network design that can endure impermanent failures while permitting recovery from such failed or disrupted networks.

2. Proposed Methodology

In this paper we propose a methodology that enables us to constantly monitor and control the entire area of the sensor network, to repair the coverage holes that are formed in the network which have adverse effects on the communication in the network. Our system works in two phases, Hole Discovery and Hole Healing. Hole Discovery mechanism further comprises of three sub phases viz., Hole-identification, Hole-discovery and Border Detection. Hole identification deals with identifying the faulty node in the network. Hole Discovery phase deals with the pinpointing the exact location of the faulty node in the network. Border Detection phase deals with identifying the neighbouring nodes of the faulty nodes. Hole Healing is further divided into two sub phases viz., Hole Healing area Determination and Node Relocation within the boundary. Hole healing area is determined by the area in which the faulty sensor node is located and its neighbouring nodes that are active. Node Relocation is done to ensure the smooth flow of the data in the system.

We employ Ad-hoc On Demand Distance Vector (AODV) Protocol for Routing with in the Network and Least Disruptive Topology Repair (LeDiR) Algorithm in our system for accomplishing the above stated tasks in an efficient and an effective way.

2.1 AODV Protocol Description

AODV is a data packets routing protocol specifically developed for its usage in ad-hoc networks, especially in Mobile Ad-hoc Networks (MANET). AODV is a demand driven Protocol, which works based on the individual sensor nodes present in the network and their need to be routed. AODV is developed for sensor networks of huge number of individual nodes. Each sensor node in the network maintains a routing table that contains the trivial data for transmitting the data packets to the intended destination.

Each of the routing table contains the following fields, which works constantly to route the packets to destination. They are Destination IP address, Destination Sequence Number, Destination Sequence Number Flag, Network Interface, Hop Count (The number of hopes needed to reach the destination from the present node), Precursor List and Life time of the route.

The basic message set of AODV protocol for Operation consists of:

- RREQ- Route Request
- RREP- Route Reply
- RERR- Route Error

The Figure 1 depicts the RREQ Packet propagation. Whenever the routes between sensor nodes holds vaild, AODV doesnot have any role to play. RREQ message is generated and broadcasted through out the network whenever a sensor node reuquires a route to reach the destination. For example, as shown in the figure there are a total of individual nodes. We've marked the origin node and the destination node in the network and the packet has to reach destination from the source selecting a path that incorporate minimal hops. Now RREQ message is enabled and broadcasted to the network. After RREQ message is activated, the intermediate nodes in the network use this to update their individual routing tables. The most recently used Sequence number to reach the destination is contained in RREQ.

The Figure 2 depicts the RREP packet path from destination to source. After the RREQ message reaches the intended destination node in the network, the route is made available and unicasted back to the source node so that it can start transmitting data. In the above example we can observe that there is a shortest path to the destination via the marked route in the network. This path is used for the entire data transmission in the network from source to destination after the RREP packet is unicasted back to the origin node. Intermediate nodes in the network renew

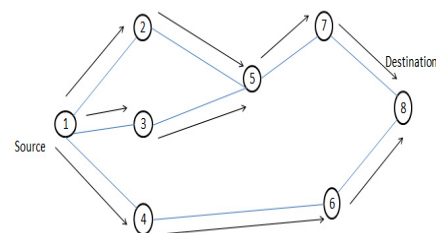


Figure 1. RREQ Packet Propagation.

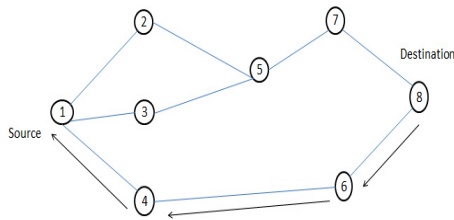


Figure 2. RREP Packet path.

their routing tables when this RREP packet is propagated back to the origin.

RERR message is an error message that is broadcasted when there's a broken link in the network. This particular REERR message can be generated from any node which detects the link failure and passed on to each and every node in the network when received from the previous node.

2.2 LeDiR Algorithm

Least Disruptive Topology Repair Algorithm is primarily employed in detecting the node failures in the network and later repairs the failure node so that the normal functioning of the network resumes after a failure is detected. Individual sensor node failures can be catastrophic for the network if it goes undetected or repaired at the earliest possible opportunity. LeDiR not only identifies and facilitates a scheme to repair the faulty node; it also minimizes the power consumption which greatly extends the battery life of the sensor node. This is one of the primary reasons for opting LeDiR algorithm over other methods in our work. The usage of LeDiR algorithm facilitates in restoration of the failed connection because of a faulty node without the need of prolonging the length of the prescribed shortest route among the sensor nodes.

The Algorithm works in the following steps to identify and repair the faulty nodes:

2.3 Hole Discovery Phase

2.3.1 Detecting the Failure Node/Hole

When a sensor doesn't transmit data to their one-hop neighbours because of various failures like power exhaustion, the node is considered to be a failed node or a hole. This detection of a failure node is a critical task. It is important to recover this as quickly as possible to ensure the normal operation of the network.

2.3.2 Identify the Smallest Block

All the one-hop neighbouring nodes in the network are considered to be the smallest block. Identifying this block after discovering the hole is an important task which plays a crucial role for replacement of the faulty node.

2.4 Hole Healing Phase

2.4.1 Replacing the Failure Node

The faulty node that is identified in the Hole discovery phase is replaced with any of the active one-hop neighbour in the smallest block. Smallest block identified in the network greatly reduces the recovery overhead.

3. System Design

3.1 System Architecture

Figure 3 depicts the system architecture. The architecture of the system is explained in the following section. Nodes in the entire network are under constant monitoring. Whenever there's a faulty node or formation of a hole in the network, it should be identified at the earliest possible instant to prevent the loss of data through the network. So, identifying the faulty node within the boundary of the sensor network plays a crucial role and this should be done with utmost care. This identification is done primarily on the energy levels of the sensor node and also the neighbouring nodes play a vital role here.

After discovering the faulty node, it is to be replaced with a working node to ensure the normal functioning of the sensor network. Replacement of the faulty node is done with the aid of an Active node in the system as

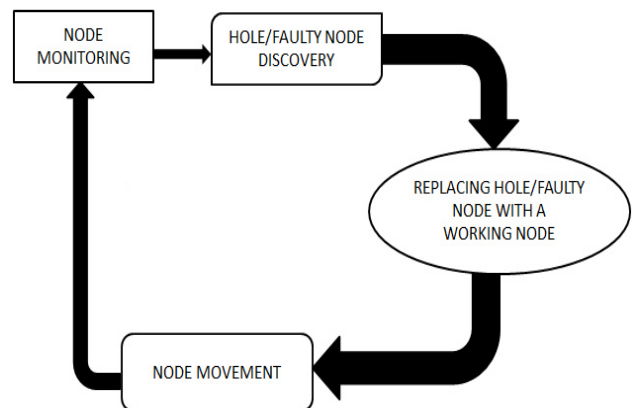


Figure 3. System Architecture.

explained in the previous section. This ensures the normal functioning the nodes resume to their normal chores.

This process continuous in a loop i.e., whenever there's a faulty node in the network, the proposed system identifies such faulty node in the network and later replaces it with a working node, in the earliest possible time to ensure the normal flow of the functionalities.

3.2 System Flow

The architecture discussed in the above section can be implemented in a graphical work flow as shown in the Figure 4. First of all the topology of the network is formed on the basis of the protocol we've opted to operate. This protocol not only defines the network topology but also defines the entire networking of the system that is in use. As soon as the network is formed and the sensor nodes are positioned according to the topology, the communication is established between the nodes and this enables the data exchange from all the nodes to the base station and vice versa.

As long as the network is working normally, i.e., there're no faulty nodes or holes in the system, data communication takes place without any interruptions. Whenever there's an interruption, in our case, the faulty node, the communication is hindered. Our system is developed in such a way that the faulty node identification is done in the earliest possible time and this node is isolated, i.e., data doesn't flow through this. Now after discovering the faulty node, we need to replace the faulty node for enabling

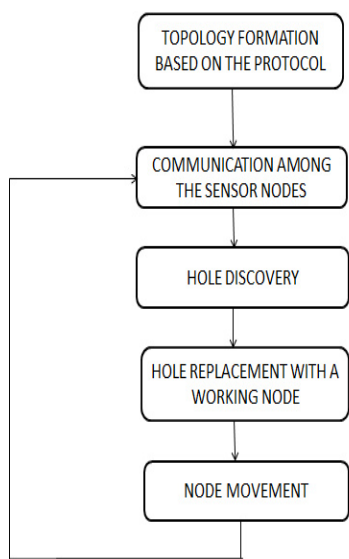


Figure 4. System Flow Diagram.

smooth flow of data. We'll be replacing this faulty node as per the design specifications we've defined for the system. After the hole is replaced by a working node, the normal communication resumes in the network and again this network is under constant monitoring to identify and replace the faulty nodes, completing the cycle.

4. Implementation

We implement our proposed system in NS-2 simulator. The following Figures clearly describe the implementation of the system we've developed for fulfilling the proposed methodology.

Figure 5 represents a typical network setup we need for the system. Here we can observe there are number of sensor nodes and each of them produce/relay the data to the next sensor nodes in the network.

Figure 6 represents the faulty node phenomenon in the network. We can observe the entire Vertical column of nodes has been unable to communicate because of the faulty nodes, this can also happen in the horizontal rows as shown in the Figure 7.

Figure 8 represents the faulty node being replaced by the Active node in the network. We can observe from the Figure 7 that this Active node can be anywhere in the consigned network boundary, like very far from the faulty node as is in our case. The Active node travels from its position towards the faulty node as shown in Figure 8.

Figure 9 represents the phenomenon where the Active node takes the place of Faulty node to resume the normal functionalities of the network. We can observe from

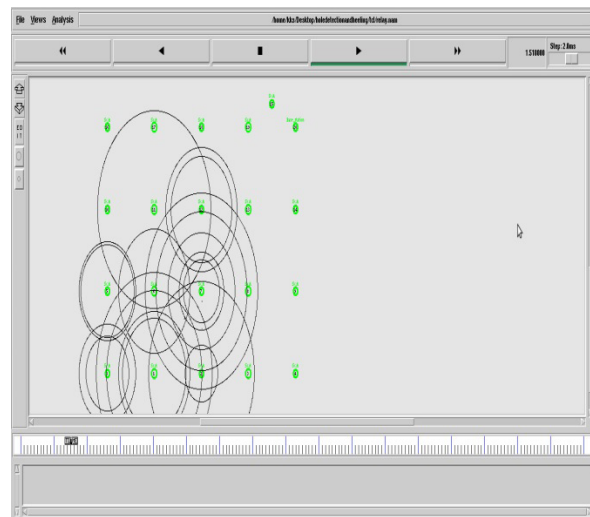


Figure 5. Network Setup.

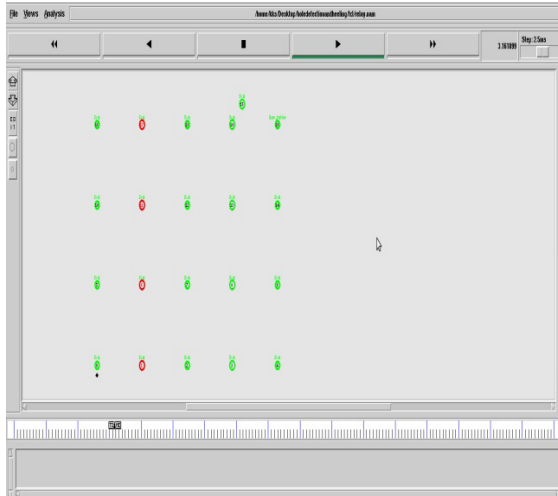


Figure 6. Faulty Node.

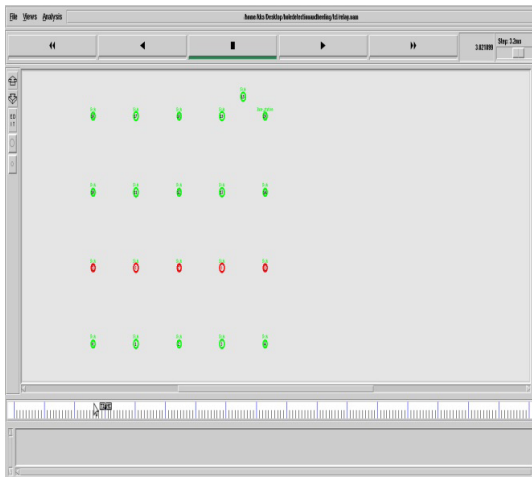


Figure 7. Faulty nodes represented in a horizontal fashion.

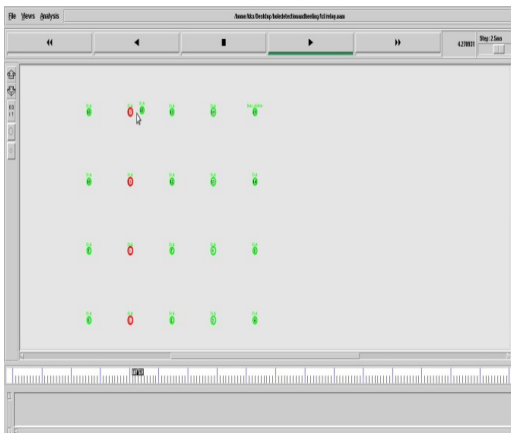


Figure 8. Faulty node being replaced by the Active node.

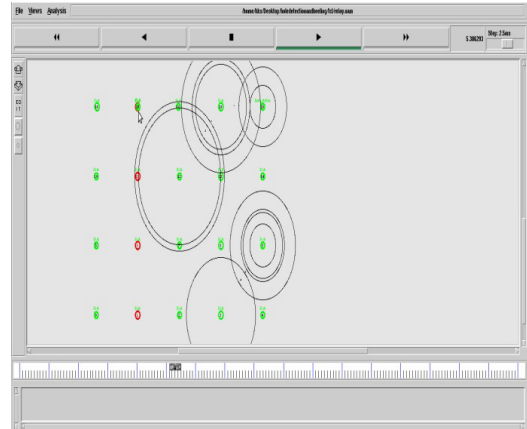


Figure 9. Faulty node replaced by Active Node.

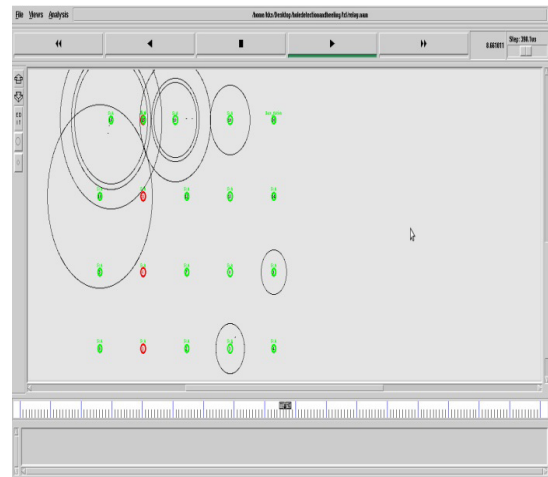


Figure 10. Normal working of the network resumed.

the figure that the moment Active node takes the position of the Faulty node; the network is repaired of the faulty node.

Figure 10 depicts the normal working behaviour of the network. As the active node replaces the faulty node, the data link is re-established and the communication resumes in the network. This network is again under constant supervision, if there're any of the faulty nodes in the network, again the same procedure is repeated to replace the faulty node with an active node.

5. Conclusion

We've successfully implemented our proposed system and evaluated the system performance. We are successful in demonstrating the system to monitor and control the total

area of a Wireless Sensor Network (WSN) without any coverage holes that impair the sensor node functionalities. Our proposed system implements LeDiR algorithm, which effectively controls the WSN of coverage holes and successful in implementing hole detection and hole healing. Our scheme is successful in overcoming both the coverage holes and routing holes.

6. Acknowledgements

We gratefully acknowledge the constant assistance and guidance of K L University in completion of this work. We also mention our special gratitude to Embedded Systems and Sensor Networks (ESSN) group of K L University for their valuable inputs and suggestions.

7. References

1. Pandey Gaurav Kumar, Singh Amrit Pal. Energy Conservation and Efficient Data Collection in WSN-ME: A Survey. *Indian Journal of Science and Technology*. 2015 Aug; 8(17):1-11.
2. Saranya R, Umamakeswari A. Energy Aware Data Aggregation with Sink Relocation to Improve the Network Lifetime. *Indian Journal of Science and Technology*. 2015 May; 8(S9):312-17.
3. Anand, Sairam N. Methodologies for Addressing the Performance Issues of Routing in Mobile Ad hoc Networks: A Review. *Indian Journal of Science and Technology*. 205 Jul; 8(15):1-10.
4. Vijayan K, Raaza Arun. A Novel Cluster Arrangement Energy Efficient Routing Protocol for Wireless Sensor Networks. *Indian Journal of Science and Technology*. 2016 Jan; 9(2):1-9.
5. Sirisha G, Bulli Babu R, Raghava Rao K. Establishing Path Quality Management in Wireless Sensor Networks through Cluster Head Determination. *Indian Journal of Science and Technology*. 2016 Feb; 9(5):1-9.
6. Vinothini M, Umamakeswari A. Reliable Data Transmission using Efficient Neighbor Coverage Routing Protocol in Wireless Sensor Network. *Indian Journal of Science and Technology*. 2014 Dec; 7(12):2118-23.
7. Sarath Chandra MS, Raghava Rao K, Ali Hussain M. An Efficient Scheme for Facilitating Secure Data Sharing in Decentralized Disruption Tolerant Networks. *Indian Journal of Science and Technology*. 2016 Feb; 9(5):1-13.
8. Shanmugasundaram TA, Nachiappan Alamelu. Multi-Layer Support based Clustering for Energy-Hole Prevention and Routing in Wireless Sensor Networks *Indian Journal of Science and Technology*. 2015 Apr; 8(S7):236-46.
9. Asha Shiny XS, Jagadeesh Kannan R. Energy Efficient Clustering Protocol using Self Organizing Map in MANET. *Indian Journal of Science and Technology*. 2015 Oct; 8(28):1-8.
10. Dugaev D, Zinov S, Siemens E, Shuvalov V. A survey and performance evaluation of ad-hoc multi-hop routing protocols for static outdoor networks. *IEEE, SIBCON*. 2015 May; p. 1-11.