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Research Paper

An efficient quantum based routing protocol with local link failure recovery algorithm for manet

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Abstract

The mobility factor of the nodes in a mobile Ad Hoc networks (MANET) changes the network topology leading to changes in size of the network. As the topology changes, link failure between the nodes takes place due to several reasons like channel interference and dynamic obstacles that give rise to severe performance degradation. Scalability and link failure recovery are the main criteria that will determine the performance of the network in terms of quality of service (QoS). While having different type of nodes, both mobile and immobile, that have several performance severity related to data transfer which is similar to the one in industrial parameter reporting and data logging, there exists a need to overcome performance related issues such as relatively faster and secured data transfer within the set of nodes. We developed the Quantum based Routing protocol (QRP) associated with Local Link Failure Recovery Algorithm (LLFR). The QRP is a routing protocol that uses DSR and AODV as an underlying protocol to improve the QoS in scalable wireless network. The QRP and LLFR establish link failure recovery spontaneously at the point of link breakage. The performance parameters like; packet delivery ratio, throughput, average end to end delay and routing overhead of the routing protocol QRP with LLFR is analyzed using NS2 simulator.

Keywords: *Ad Hoc Network, Link Failure, Routing Protocols, Scalability, Quality of Service*.

1. Introduction

The mobile network using both mobile and immobile nodes that are free to move has a fixed geographic topology but changes its link between its neighbors in due course of time over time. The establishment of communication is extremely challenging due to the dynamic nature of nodes that necessitates the need for having efficient data transmission. Since the routing process is associated within the mobile nodes, the routine exercises pertaining to the network such as exploring the network topology and transmitting the data are performed by the node itself.

The mobile network with self-determining nodes communicate via confined wireless bonds in a widespread geographical area, requires specified protocol to perform a defined routing function. The routing protocols in MANET [1] are categorized into three types, namely pro-active, reactive and hybrid routing protocols. In proactive routing protocols, every node in the network maintains the routing table that is updated regularly. The nodes exchange the topology information to keep the routing table with latest notifications leading to high overhead, as they are flooded with information pertaining to unknown links. In QRP, we use DSR and AODV- the reactive protocols, as we proceed in this paper.

Ad hoc On-Demand Distance Vector, (AODV) [2] is a reactive routing protocol used in wireless networks that discovers a route to destination on demand. AODV requires each node to maintain a routing table containing the discovered path information. AODV is capable of creating fresh routes whenever a route error occurs. The advantages of AODV is that, it uses sequence numbers to determine the freshness of the route thereby preventing loop formation and doesn't create overhead unnecessarily during communication.

Dynamic Source Routing, (DSR) [3] is designed for infrastructure less network and provides loop free routing. It is a reactive routing protocol that uses a source routing approach in which the route cache stores the routing information for its later use. In DSR, each node acts as a source and is responsible for neighboring node for receiving the transmitted

data packet. The route caches present in each node is directly responsible for the lesser route discovery overhead. A route in DSR would result in many routes to the destination because of the intermediate nodes replying from route caches.
MANET's have become highly adaptable to all the groups, as human society relies on portability of devices which enhances the importance of wireless connectivity in work places, offices, colleges, hotels etc. Routing in MANET [4] is always a typical task and it becomes a challenge to have an appropriate routing scheme when the network size grows more sizeable. Owing to the mobility of nodes in a wireless network, the network topology changes and the route length between the source to destination increases. Existing reactive protocols are suitable for limited number of nodes for obtaining an optimum performance. When the link between the nodes in a network suffers due to mobility or increase in topology, the reactive protocols like DSR and AODV generally drops the original route and triggers a new route discovery process causing overhead in local route discovery. The rerouting is an energy consuming process that heaps the overheads on the nodes. The motivation of this work is (i) to implement an effective routing protocol for scalable networks, thereby reducing the overhead influenced due to generation of periodic messages that is required to maintain hierarchies (ii) to overcome link breakages, by recovering link failures locally and establishing routes without further losing the data packets.
In this paper, we introduce the Quantum based Routing Protocol (QRP) that uses AODV and DSR protocols as underlying protocols along with a novel Local Link Failure Recovery algorithm (LLFR) for recovering from link failures locally. The QRP works with the networks where both the flat routing protocols are available. The flat network routing is chosen so that maximum scalability is achieved, as each node in the network with equi-function will participate in the routing processes. The minimum hop count [5] is calculated by the source node and is used as a prerequisite to QRP, enabling it to choose the routing protocol that is used between that particular source and its destination. The QRP is usually pre-registered with a set value called the minimum hop value that will determine the choice of the flat routing protocol to be implemented. i.e., When the minimum hop value is less than or equal to the set value, the DSR becomes active in that route. When the minimum hop value is greater than the set value, QRP understands the distance between the source and its destination and activates AODV for that route.
When a link failure occurs due to faint signal between nodes due to high mobility in large size network topology or due to dynamic obstacles, the route has to be configured and repaired spontaneously so that there is no data loss, which is the function of Local Link Failure Recovery algorithm. If a link failure is detected by a node, the Local Link Failure Recovery (LLFR) mechanism deployed in each node arrives on an alternate path from that intermediate node which did not receive the RREP i.e. the failed node. The LLFR then updates the alternate path to source and sends the data packets to the destination much faster, instead of dropping the whole route and discovering a new route to the destination. The overhead among nodes are significantly reduced as the failure recovery is done locally. The packet delivery ratio also increases, as preventive measures for safe landing of data packets to the destination are taken in the new route, by keeping a constant tab on the signal strength of neighboring nodes. Compared to the reactive protocols the task of effective routing during conditions like link failures in dynamic Ad hoc networks, overcoming the data packet loss, is significantly improved. As a whole, this mechanism exhibits better efficiency by overcoming the overhead issues in handling larger networks and during link failures.
This research paper presents the related work in section 2, the proposed system in section 3, the results in section 4 and the conclusion in section 5.

2. Related work

AODV has been proposed by IETF [4] and is intended for use by mobile nodes in Ad Hoc Network for routing purposes. It provides hop by hop routing using route discovery and route maintenance schemes [8]. It also provides local repair to recover the route when a node detects the broken link in an active route by rerouting and this process consumes comparatively more time.
In AODV, a route discovery phase is implemented on-demand when a route fails and the route maintenance phase starts by flooding a route error message over the network. By its architecture, the AODV increases its route discovery process quite frequently thereby increasing the overhead. To improve the problem of overhead caused during route discovery process, several studies has been established like the partial re-establishment approach and the multipath approach. In partial re-establishment approach, the routing protocol finds an alternate route during the route maintenance phase [7]. In multipath approach, the routing protocol establishes many routes during the route discovery phase. As the Multipath AODV [8] [9] establishes possible number of multiple routes regardless the route efficiency, there can be a large number of inefficient routes associated with the route discovery process which leads to enormous routing overhead. The packet drop and latency is more in multipath AODV, as this protocol depends on unused routes too. Even though multipath routing is significantly better than single path routing, the performance advantage is too small. Local self-reconfigurable route repair schemes introduce special route maintenance techniques to repair broken links.
The Bypass-AODV [10] uses cross-layer MAC-notification to determine mobility-related link failure, and sets up a bypass between the broken link end- nodes via an alternative node while keeping the remaining nodes of the route as it is. The performance of Bypass-AODV is enhanced compared to the traditional AODV, as the error recovery phase is eliminated thereby reducing routing overheads and packet drop ratio. The Bypass-AODV transmits the packets via the

newly constructed bypass route eluding packet drop. The performance of Bypass-AODV is best at high node density, when the distance between the end-nodes is greater than or equal to three hops. At low density of nodes where node connectivity is low, Bypass-AODV is not suitable due to occurrence of collision.

Mobility prediction and routing [11] [12] is used to overcome route failures by obtaining local route repair, when a link break is about to occur. The mobility information from each node is used to predict the instant when the link between two neighbors will break. The location and motion pattern of each neighboring node is recorded via an extended-Hello message that is generated from nodes belonging to the active routes. The information pertaining to location and mobility of the nodes is constantly reproduced between neighbors and hence incurs huge overheads.

In Multi-Rate AODV (MR-AODV) [13], path gain is used to select an optimal route between the source and destination nodes. The path gain considers both hop count and optimal data rates at each hop for a given path. Since RREQ & RREP packets are modified to append path gain and link gain involving arithmetic calculations, the end to end delay is considerably more. Even though MRAODV avoids link breakage, it is suitable for networks where node distance is comparatively larger since route discovery takes 50% more time than that of a traditional AODV.

Even though the Hierarchical protocols [14] achieve the goal of scalability, they have their own disadvantages as they require periodic messages from each node, in order to maintain the hierarchies. The generation of periodic messages results in higher overheads, as well as increased bandwidth usage and longer delays. Moreover, leader nodes of clusters may drain their batteries comparatively sooner as they play a major role in routing. Although there are several mechanisms to overcome link breakage and link failure recovery, each has its own limitations. We propose that localization of link failure recovery will reduce the overhead of route discovery and is essential for ad hoc routing protocols to improve its QoS parameters.

3. System description

3.1. Overview of the system

It has been widely accepted that routing in MANET is a challenge, as the network size increases. When the size of the network grows, the number of nodes in the network increases and simultaneously the distance between the source and destination increases too, due to which the nodes find hard to handle the network traffic effectively. The highly dynamic and unstable nature of mobile nodes in large scale Ad Hoc networks causes radio links to break frequently. Cluster based hierarchical routing protocols are popular in handling topology based issues in large scale wireless Ad Hoc network, but they incur node failures that would lead to the re-election of a new cluster-head which may cause re-election of the cluster structure, thereby degrading the network performance. In such cases, traditional routing protocols perform re-routing during link failures. We implement the Quantum based Routing Protocol (QRP) with Local Link Failure Recovery Algorithm (LLFR) by deploying in all the nodes present in the network and observed that the network implemented with QRP with LLFR (i) performs efficient routing of data packets by means of protocol selection (ii) overcomes issues pertaining to overhead caused to nodes during link failures (iii) performs local route recovery during link failures in ad hoc network instead of re-routing (iv) Improves QoS parameters like the packet delivery ratio, average end to end delay and throughput. It is also presumed that by implementing QRP with LLFR in an Ad Hoc network, the power consumption of each node reduces considerably and the factor of power saving is not covered in this paper.

3.2. System architecture

The QRP with LLFR is deployed in all the nodes present in the 802.11n based wireless Ad Hoc network. The system consists of the modules viz; Quantum based Routing Protocol and the Local Link Failure Recovery mechanism. The fig.1 depicts the system architecture.

3.2.1. The Quantum based routing protocol

The objective of QRP is to basically address scalability related issues in MANET by using on demand routing protocols like source routing (DSR) and distance vector routing technique (AODV) judicially. QRP basically consists of two operating modes viz the DSR mode and the AODV mode. As the name depicts, QRP estimates the minimum hop count value using Poison randomization tool and selects the appropriate routing protocol for data transmission, governed by the QRP mode selection constraints, based on the quantum of nodes between the source and the destination. DSR is used for shorter routes because (i) the packet header in DSR carries the complete route information (ii) It reduces overhead during transmission (iii) it reduces network bandwidth overhead conserving battery power as there are no periodic routing messages, (iv) The routes are maintained only between nodes that need to communicate; reducing route maintenance overhead and (v) Route caching that reduces route discovery overhead. We use AODV for longer routes because (i) The destination sequence numbers are used to establish route on demand to the destination, (ii) It responds quickly to the topological changes that affects the active routes, (iii) It chooses the less congested route instead of the shortest route and (iv) It supports both unicast and multicast packet transmission.

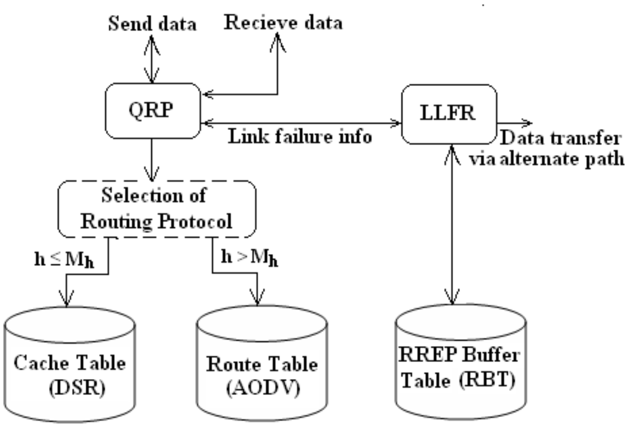

Fig. 1: System Architecture. All Letters Used in the Figure Are Explained in the Caption: QRP = Quantum Based Routing Protocol, LLFR = Local Link Failure Recovery, H = Hop Count, M_h = Minimum Hop Count, DSR = Dynamic Source Routing Protocol, AODV = Ad Hoc on Demand Distance Vector Routing Protocol, RBT = RREP Buffer Table

3.2.2. Necessity of using traditional routing protocols

DSR and AODV are the two reactive routing protocols having high packet delivery ratio compared to the proactive routing protocols. DSR uses source routing and are able to obtain multiple routes. The routing packets of DSR consist of the complete route information and do not depend on the routing table, as every node maintains the freshness of the entry. DSR easily recover from link failures by sending the data packets via alternate route, since each node enroute are dynamically a source. By virtue of its property, in source routing, the routed packets will contain the address of each node it travels resulting in high overhead for long paths or large addresses. Since DSR is suitable to run on smaller networks and not comfortable in larger networks due to its overhead issues, to overcome such dismaying situation, we use AODV for longer routes. AODV does not employ source routing of data packets, and it maintains the route until it is active. If a link break occurs while the route is active, the node upstream of the broken link propagates a RERR (Route Error) message to the source. After receiving the RERR message, the source node reinitiates route discovery. In order to avoid re-discovery of route from the source, the QRP with LLFR algorithm that is implemented in the intermediate node, upon notification of the link failure, identifies an alternate path for data transmission keeping a tab on signal strength of the downstream nodes. AODV is capable of running in larger networks except for which it has high end to end delay during link failures. This end to end delay during link failures is overcome by the LLFR by routing the data packet from the point of link failure. We use DSR as well as AODV as the base routing protocols in Quantum based Routing Protocol (QRP) for the reason of picking up the stand-alone advantages of both the routing protocols for improving the network efficiency. Hence QRP activates DSR when the hop count of the selected route is less than the set value, and AODV is activated when the hop count is greater than the set value.

3.2.3. The routing scheme

The quantum or number of nodes between the source and the destination is quantified and compared with the minimum hop count (min_hop_cnt) value assigned to the QRP. The parameter min_hop_cnt determines the selection of the routing protocol based on the quantum: hop count value. The QRP deployed in each node updates its hop count upon receiving the RREQ from the upstream nodes. Considering the nodes between the source and destination, if the hop count of the receiving node (RECG_ node) is less than or equal to the minimum hop count (hop_cnt of RECG_ node ≤ min_hop_cnt), QRP works in DSR mode and when the hop count is greater than the minimum hop count (hop_cnt of RECG_ node > min_hop_cnt), QRP works in AODV mode. This is because, the DSR approach works well for smaller networks, and when the routes become longer the performance of AODV is preferred than the DSR due to its dominant characteristics. When QRP works in AODV mode, a source node requesting a new route to the destination node will initiate a route discovery by broadcasting route request ($RREQ_{QRP}$) packet to its neighbors. The $RREQ_{QRP}$ packet contains the following fields viz; <src_addr, src_seqnum, brdcst_id, dest_addr, dest_seqnum, hop_cnt, signal_strength >. The $RREP_{QRP}$ packet contains the following fields: <src_addr, dest_addr, dst_seqnum, hop_cnt, life time, signal strength>. Signal strength [12] has been used as link quality metrics in wireless Ad Hoc networks. Signal strength is used as a good indicator of the link quality in LLFR routing scheme. A node receiving the $RREQ_{QRP}$ would send a route reply ($RREP_{QRP}$) if it has a route to the destination with the sequence number equal to or greater than the sequence number present in the $RREQ_{QRP}$. If an intermediate node receives a $RREQ_{QRP}$ which they have already processed, they simply discard it. Unless there exist a link failure, the source transmits the data to the prescribed destination.

3.2.4. Estimation of minimum hop count

The min_hop_count (M_h) is estimated by the tool derived using Poissons randomization theorem [6].

$$P\left(M_h = m_h\right) = \sum_{n=m}^{\infty} e^{-\lambda L} \frac{(\lambda L)^n}{n!} P(M_h = m_h \mid N = n)$$

Where $P(M_h = m_h|N = n)$ is the probability distribution of minimum hop count, 'N' the number of intermediate nodes and 'n' the probability of intermediate node, 'M_h' the minimum hop count and 'm_h' the probability of minimum hop count. QRP estimates the distribution of minimum hop count between source and destination nodes via its intermediate nodes N. X_j denotes the location of intermediate node j, where j = 1, 2 . . . N and $X_0 = 0$ denote the location of source node and $X_{N+1} = L$ denote the location of the destination nodes. $X_{(j)}$, j = 0, 1. . . N+1 denote the location of j^{th} node from the origin, i.e., $0 = X_{(0)} < X_{(1)} < . . . < X_{(N+1)} = L$.

3.2.5. The QRP with LLFR algorithm

The algorithm (1) describes the function of QRP with LLFR during the process of recovering from link failure.

Algorithm 1: QRP with Local Link Failure Recovery Process

1) Route Discovery(R_d)

```
Broadcast RREQ to DSn
if (hop_cnt of rec_node <= min_hop_cnt)
DSR activates
else AODV activates
if (RREP received by DSn) then
Store received RREP in ascending order of signal strength to RBT
Simultaneously forward RREP to USn
Sn sends data packets to DSn
end if
```

2) Link failure detection

```
If node j detects link failure then go to step(3)
Else node j sends data packets to DSn
End if
```

3) Local Link Failure Recovery (LLFR)

```
Choose first RREP of DSn entry in RBT stack and select as next DSn.
J sends data packets to DSn and update the new route to Sn If DSn is not destination.
Relay LLFR While reach destination.
```

LLFR (16) incorporated with QRP deployed in every node waits for the receipt of link failure information from the downstream nodes DS_n. It updates the RBT with RREP packet in ascending sequence of highest signal strength from relevant downstream nodes. So when a link failure is detected, the foremost RREP stored in the RBT will be chosen as the next downstream node and this process continues until reaching the destination. The alternate path is updated with the source node and the routing table of all relevant nodes.

4. Main results

The Quantum based Routing protocol with Local Link Failure Recovery Algorithm (QRP with LLFR) is implemented and evaluated using the Network Simulator (NS 2, version 2.32). The NS2 provides substantial support for simulation of wireless networks and is more user friendly meeting diverse needs. NS2 is a cost effective solution that is alternate to real world network used to evaluate and analyze the behavior of various network design. The parameters used in our simulation are shown in table 1.

Table 1: Simulation Parameters

Radio propagation model	Two Ray ground
Mobility Model	Random Way Point
MAC Type	MAC802.11n
Antenna model	Omni Antenna
No. of mobile nodes	100
Routing protocol	LFR
Terrain	1500m x 1500m
Length of data packets	512 bytes
Simulation time	500 seconds
local repair wait time	0.15 seconds
maximum RREQ time out	10 seconds
RREP wait time	1 seconds

The simulation results of LFR routing protocol are given below.

4.1. Packet delivery ratio

It is the ratio between the numbers of packets received by the application layer of destination node to the number of packets sent by the application layer of source node.

$$PDR = \frac{P_{recd}}{P_{sent}} \times 100$$

Where PDR is packet delivery ratio, P_{recd} represent the total number of data packets received and P_{sent} represent the total number of data packets sent. The simulation results shows that the packet delivery ratio of QRP with LLFR routing protocol has increased when compared to AODV routing protocol. It is also observed that the PDR of QRP with LLFR is relatively consistent or even better during link failures, as compared to AODV in such situations. When there are more failure nodes, the QRP with LLFR tends to have a better PDR when compared to the AODV that has very low PDR in situations like node failures.

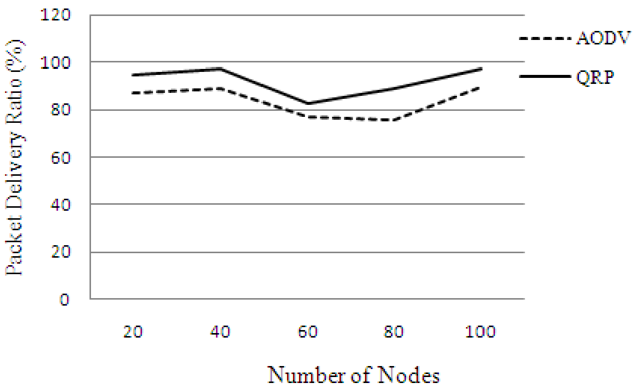

Fig. 4: Packet Delivery Ratio

4.2. Throughput

Throughput is defined as the number of bits transmitted per unit second over a communication channel.The figure shows the results obtained in comparing the working of QRP with LLFR and AODV routing protocol.
The average delay of transmitted data packet is calculated using simulation by dividing the total delay by the number of packets arrived at the destination. The simulation results show that the throughput of QRP with LLFR is significantly better compared to AODV even when situations like kink failure. The QRP with LLFR achieves better throughput when compared to the other case, as the alternate path chosen by the LLFR is reliable leading to better throughput.

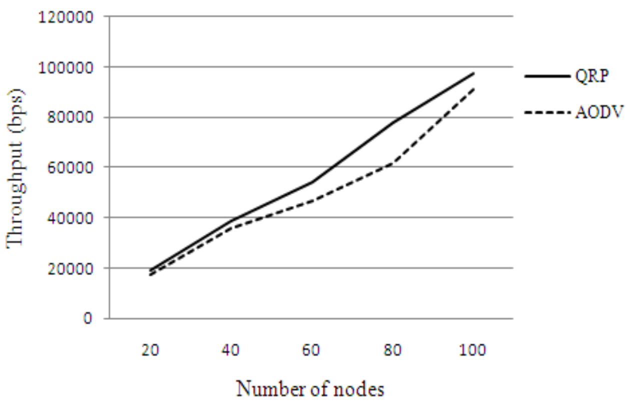

Fig. 5: Throughput

4.3. Average end-to-end delay

End-to-end delay is defined as the time taken for a data packet to be transmitted across a wireless network from the source to destination.

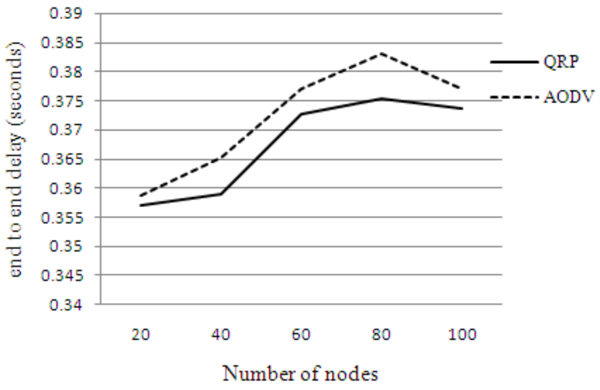

Fig. 6: End to end delay

The figure shows the average end to end delay is reduced considerably in the QRP with LLFR when compared to AODV routing protocol in conditions of node failure. This has been achieved by allowing the intermediate node to spontaneously choose the alternate route during the link failure.

4.4. Protocol overhead

Protocol overhead refers to the number of routing messages requested when a data packet is successfully delivered to the destination. From the simulation results, we find that the QRP with LLFR has reasonable lower overhead when compared to AODV. In traditional AODV, mobile nodes respond to link failures and changes in network topology with numerous messages that are flooded across the network to maintain an active route in AODV, resulting in high overheads. The QRP with LLFR routing Protocol has the best overhead performance because of its unique routing policy and its spontaneous response to link failures.

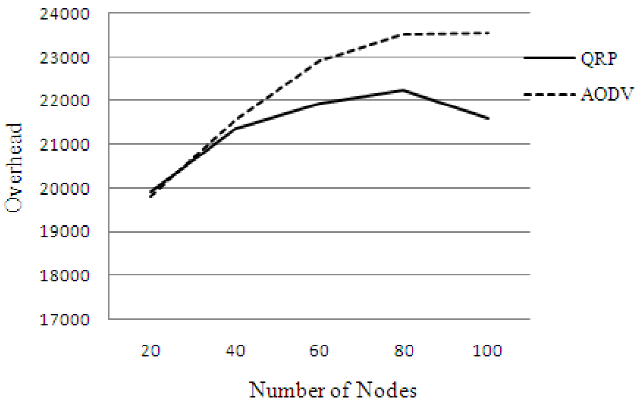

Fig. 8: Routing Overhead

5. Conclusion

The QRP with LLFR routing protocol provides significant improvement in the QoS demands of larger wireless Ad Hoc network which has both mobile and fixed nodes. The performances of routing protocols also rely up on the number of nodes or participants in the network. We considered a situation where the environment monitoring instruments in an industry has set of instruments delivering data to the local monitoring station. The effluent treatment plant is situated in an extreme end of the industry that collects data locally where different types of instruments are measuring different parameters. While the rest of environment monitoring devices located across the plant collects data in a control room before data transmission to the environment monitoring station. The QRP triggers DSR when only a set of nodes is functional and AODV is triggered when the number of nodes is well improved. The LLFR algorithm is included to improve packet delivery even during link failures. The performance of QRP with LLFR routing protocol is compared with AODV in terms of packet delivery ratio, routing overhead, throughput and average end to end delay and found significantly better in all aspects. The QRP with LLFR achieves better packet delivery ratio compared to AODV as shown in the simulation result. The overhead of QRP with LLFR is significantly low compared to AODV, as the functionality is need-based, overcoming the unnecessary overheads caused by the routing nodes. The end to end delay is improved in QRP with LLFR as the QRP chooses either DSR or AODV depending upon the distance between the source and the destination to overcome the delay as well as transfer the data packets efficiently during link failures thereby reducing the overall delay in transmission. The simulation results show that the QRP with LLFR significantly increases the throughput and reduce delay.

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