Mobility Management in Constrained Wireless Nodes: A Review

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Abstract: The key aspect of IOT is interoperability, the potential of different technologies, different hardware platforms, various communication protocols, different operating systems to communicate with each other. Mobile support is required for interoperability between fixed and mobile nodes. As wireless nodes have certain limitations, like reduced power, low-energy and limited resources, attention is required while designing the mobility management scheme. The main challenge in Low Power and Mobile Network is to provide Quality of Service along with the support of mobility. In this paper, latest work in the mobility support of RPL has been discussed in detail along with their contributions and shortcomings.

Index Terms*: *RPL; LPWN; LLN; Mobility; LPLN; IOT

I. INTRODUCTION

Routing Protocol for Low-Power and Lossy Networks (RPL) [1] is an IETF IPv6 protocol used for routing between sensor nodes. Basically, RPL was devised for stable topologies, number of developments have been lately proposed to handle mobility and aid the flows of traffic from mobile nodes towards a stationary gateway. [2, 3, 4, 5]. For example, nodes used for auditing the quality of air in intelligent transportation systems (ITS) are mobile, in healthcare applications, regular supervision of patient needs direct transmission flow between data originator (patients) and data collector (doctors), both being mobile nodes.[5]. The key aspect of IOT is interoperability, the potential of different technologies, different hardware platforms, various communication protocols, different operating systems to communicate with each other. Mobile support is required for interoperability between fixed and mobile nodes.

Two native algorithms used in RPL to support mobility are: Trickle and Neighbor Discovery [1]. These techniques are Reactive in nature, i.e. they come into play after the node mobility. Thus, native RPL/ 6LoWPAN protocols possess large packet loss, higher message latency and high delays and overheads. To provide better network connectivity, distributed mobility management is required in IOT applications. Because of the following features, high power wireless networks have different mobility solutions:

- Existence of wired base stations that serve as backbone to the network.
- Possession of platforms that have large processing ability.
- Assistance of multiple antennas (radios)
- Location info aided by hardware like GPS.
- Whereas Low Power Wireless Networks:
- Don't have a firm support of Wired APs.
- Exhibit low energy, processing power and communication resources.
- Links are short range, unreliable and dynamic.
- Hand off in distributed architecture is activated on quality degradation of source.

Hence, mobility management solution for Low Power Lossy networks must be

- Agile (in terms of less overheads and lesser control messages exchanged).
- Fast (short network inaccessibility period during hand off).
- Reliable (PDR remains almost same on mobility of node).

The main challenge in Low Power and Mobile Network is to provide Quality of Service along with the support of mobility. Two algorithms that moderately support mobility in RPL and 6LowPAN are:

1. Trickle algorithm which sets the interval of sending control packets depending upon the topological changes encountered. This interval is minimum when any change in topology is detected and increases with increase in stability of the network.
2. Neighbor Discovery algorithm which detects for the reachability of neighbor on regular basis by sending beacons.

"RPL expects an external mechanism to be triggered during the parent selection phase in order to verify link properties and neighbor reachability" [1]. On triggering these algorithms, RPL overwhelms the network with control packets leading to network congestion. This results in wastage of energy and high overhead. There is a trade-off between responsiveness of these algorithms and overhead caused by them. In stable networks with low traffic, if these algorithms are triggered moderately, although this cuts down the overhead, it leads to depressed responsiveness to changes in topology of network.

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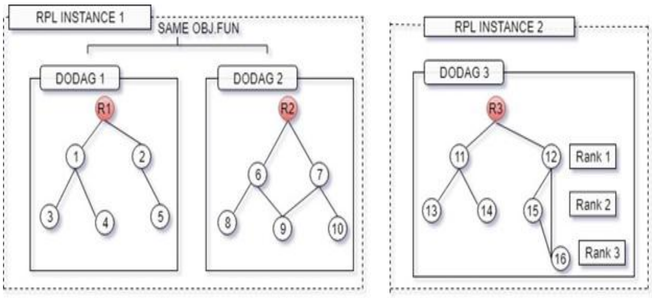

Figure 1: Two RPL instances with three DODAGs.

In case these algorithms are activated often for high responsiveness, upon encountering no mobility (no topological changes), network resources are wasted because of flooding of control packets. Hand Off refers the process of shifting from one pint of connection to another. This involves choosing a new preferred parent for further communications. There are two types of hand off:

• Hard Hand Off: also referred to as Break Before Make. In this scenario, ongoing link among the mobile node and its parent (access point) is released before activating a new connection.
• Soft Hand Off: In this, link between the moving node and its' going to be parent is built prior to the current connection deactivation.

II. Working of RPL

RPL stands for routing protocol designed specifically for low power Lossy networks. Low power wireless networks are the networks that have limited bandwidth resources and energy. It is an Internet Protocol version 6 based distance vector routing protocol supporting data rate of not more than 250kbps and has low throughput due to high error rate in communication [6, 7].
As shown in Fig 1, the nodes, in RPL routing protocol, are arranged in Destination Oriented Directed Acyclic Graph (DODAG). For defining a path, each RPL router selects a collection of preferred parents. These stable parents act as intermediate hop while transmitting(data) up towards the root of DODAG. Each DAG is identified by at least one root. Root is a node with no out-degree. Based on the criteria of parent selection, out of collection of stable parents, one is elected as "preferred parent" for carrying out communication towards the root.
The network may consist of more than one DODAGs. Each DODAG is characterized by the following identities:

1. RPLInstanceID – identifies set of independent DODAGs that have same objective function.
2. DODAGID - identifies DODAG root. It is unique within the scope of an RPLInstanceID. DODAG is uniquely identified by the tuple (RPLInstanceID, DODAGID).
3. DODAGVersionNumber – It increases on some particular even like reconstruction of DODAG.

Rank is an integer assigned to each node that indicates the distance from the root. It increases in the direction away from the root, i.e. downstream direction and vice-versa. Rank of root node is 0. Rank represents position of node within a DODAG Version.

The objective function evaluates the rank value depending on measures like connectivity, delay, link quality, and assign these rank values to each router. Depending on these rank values calculated by objective function, preferred parent are associated with each router during the construction phase of network topology. [8]. By default, Expected Number of Transmission (ETX) [9] is used as a metric in calculating objective function and rank value of each node.
In Fig 1, Node 16 has a higher rank than Node 15, and Node 15 has higher rank than Node 11 and Node 12. RFC 2463 [10] defines four types of Control Messages in RPL, which are updation of Internet Control Message Protocol version 6 (ICMPv6). These are: DODAG Information Object (DIO), DODAG Information Solicitation (DIS), Destination Advertisement Object (DAO), and Destination Advertisement Object Acknowledgment (DAO-ACK). The working of this protocol is based on 4 control messages, DIO, DIS, DAO and DAO-ACK.

DIO: Initially generated by root node, this message is then broadcasted by other nodes. It carries information required for development and maintenance of DODAG tree. Details like rank of node, address of root, RPL Instance, held in DIO message, help in discovery of RPL Instance, determining its parameters, selecting stable parent set for DODAG.
- DIS: It is a request message for the delivery of DIO. It is multicasted by nodes that desire DIO message from their neighbors.
- DAO: For enabling downward route from root to itself, a node transmits this DAO message. This message is sent towards the root of DODAG for establishment of downward path.
- DAO-ACK: This is acknowledgment messages sent by receiver of DAO message after successfully receiving DAO.

A. Procedure for Route Set Up

- DIO message is broadcasted[11] by root of DODAG.
- Based on the information in this DIO message, each node nk evaluates its rank and routing metric.
- Depending upon the rank value received, each node nk selects its preferred parent among its neighbours and joins the DODAG.
- A new DIO message is broadcasted to its neighbour by node nk.
- Above steps are repeated till all the nodes in the network receive
- DIO message.
- If a node (say mobile node nj) is willing to be part of DODAG prior to receiving of any DIO, it broadcasts DIS message in order to enquire a DIO for joining the DODAG.
- Joining node nj sends DAO message to the sink for creation of downward link from root to the node.
- DAO-ACK is sent by each node receiving DAO as an acknowledgement [12].

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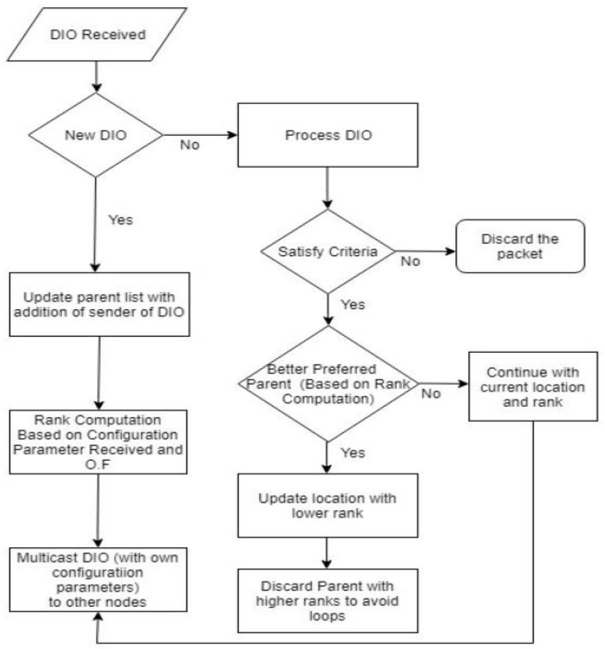

Figure 2: Operation Flow for router.

B. Downward Route Establishment

The routing of data takes place after the development of destination oriented directed acyclic graph, DODAG and for the formation of DODAG and selection of DODAG root, DIO messages are exchanged. To build up the downward routes (routes heading away from the root towards the network nodes), DAO (destination advertisement object) messages are used. Though the formation of these routes facilitate P2P communication among network nodes, it persuades to larger traffic overhead (of control packets) and higher demand for memory and processing for DODAG roots (and nodes near to root). Mobility of nodes causes topological changes followed up by disconnection with neighboring nodes resulting in packet loss.

1. Downward Route in RPL:

Downward route refers to the route from DODAG root towards the (desired) node having rank less than that of root. This root is necessary to send packet to node of RPL network [13]. However, this route fails when a node becomes mobile. The following section illustrates current mechanism employed for construction and maintenance of these routes.

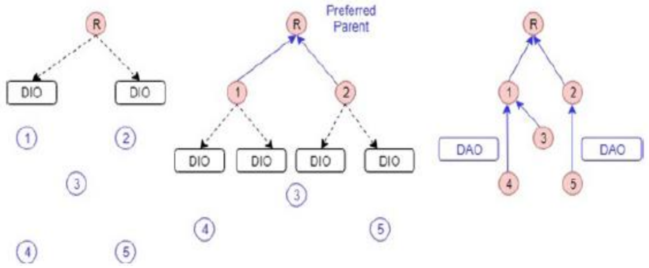

Figure 3: Construction of DODAG a) Broadcasting of configuration parameters via DIO by root b) Propagation of DIO message by surrounding nodes after selecting (root as) preferred parent. c) After construction of DODAG, nodes transmit DAO for establishing downward route.

2. Downward Route Construction:

The creation of the downward routes is originated by the node where the data is to be received(destination), i.e. downward route construction follows “bottom up” approach. DAO (destination advertisement object) messages are send by node that requires this route to be set up, towards the root via its preferred parent. DAO message as an option field also carry the information regarding the lifetime of the route. Following this procedure, roots of DODAG are informed of the destination via DAO message.

There are two modes of operation while dealing with DAO messages

(i) Non Storing Mode: In this mode, intervening nodes simply transmit the DAO message towards the sink, no information regarding the destination is stored. This results in sink exclusively having the information regarding the exact topology. IP source routing is used for the downward routed packets, i.e. in the packets’ header of the packet routed downwards complete route details are injected by the sink.

(ii) Storing mode: In this mode, in-between nodes store the downward node information in their routing table while forwarding DAO messages up towards the sink. This routing table helps to route the downward routed packets with help of their IPv6 destination address.

3. Downward Route Maintenance and Update:

A new DOA message is initiated by a node, say X, if it receives a DAO message that has different set of prefixes from the one that are already communicated by the node X. This new DAO message is then advertised further to its parents. So as to assemble the details of all nodes, transmission of this DAO has to be postponed. According to RFC the default value for this delay is 1 sec.

(i) Deletion of Downward Route:

DAO messages having existence value equal to zero are known as No- Path DAO messages. These messages are initiated by (mostly to be mobile) nodes to inform their parents of the invalidity of the path heading towards them. An intermediate node receiving this No-Path DAO messages further forwards them to its parents so as to notify them about the cancellation of downward route towards the node originating No-Path message. This route cancellation can also be sent when a neighbor becomes unreachable, or a mobile node is unable to reach its parents or to announce a forwarding error. After this mechanism of route cancellation via propagation of No-Path DAO, node advertises a DAO message for downward route construction towards its new parent. Again, to accumulate DAO info of other nodes, RFC suggests to delay the propagation of a DAO message.

(ii) P2P Routing in RPL:

The construction of downward route is mandatory to carry out communication between any two nodes in a network. According to RFC [1] “A packet propagated upwards two the root until it encounters a parent common to the destination.” DODAG root serves as common ancestor in case there exists no common ancestor.

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If invalid downward route from a common ancestor in sub-DODAG is not deleted, then messages from every other node will in sub-DODAG will follow this non-existing path, resulting in packet loss.

4. Downward Route to Mobile Nodes:
This section discusses few drawbacks that RFC faces while dealing with mobile nodes. As discussed in above section, RFC performs following two steps when a mobile node switches its parent.
(i) Node generates a No-Path DAO to earlier parent.
(ii) Then, node transmits DAO to new selected parent for downward route construction as discussed earlier.
This procedure can result in erratic routing state in case the mobile node is unable to send the No-Path DAO to old parent due to its unreachability or when there is loss of No-Path DAO message due to certain reason. In such situation, the older invalid downward path exists till the route's validity expires. The recurrence of this inconsistent routing state relies on the packet loss and velocity of migration of the mobile node, thereby resulting inaccurate routing information within the tree. Inconsistency may also arise when mobile node sends DAO to new preferred parent (after deletion of older path) and this parent becomes unreachable, resulting in packet loss as older path is destroyed and new path is not constructed as DAO messages responsible for generation of downward path remain undelivered to unreachable new parent.

III. MOBILITY DETECTION IN RPL

RPL implies two mechanisms for detection of mobility (i) Transmission of ICMPv6 control packets managed by Trickle Algorithm. (ii) Transmission of ICMPv6 control packets managed by Neighbor Discovery Protocol [2].

A. RPL Trickle Algorithm

Traditionally, to manage the state of low power networks, control packets were broadcasted at fixed periodic intervals[14]. This approach had trade-off between bandwidth wasted and reactiveness to the changes in network. Fixing a small periodic interval results in wastage of bandwidth and energy in case of a stable network. However, in case of larger periodic intervals, less bandwidth and energy are required, but these are less reactive to network dynamics resulting in topological problems.
In Trickle [RFC 6206] [14], control packets are propagated on detecting any change in the topology. Rather than periodic transmission, sending of DIO messages is controlled by Trickle Timer used in this mechanism. Being a flexible beaconing approach and reactive in nature, this algorithm results in rapid recovery and less overhead. As discussed in working of RPL, nodes regularly transmit DIS packets till the discovery and selection of parent node. However, interval transmission of DIOs is increased exponentially in case of stable network situation and is rapidly decreased to minimum whenever any topological changes are detected in the network. The maximum and minimum limit of this time interval of DIOs is defined by [Imin , Imax]. Imin is minimum time interval in milliseconds and Imax = Imin * 2k. This is used restrain the number of times this minimum interval can double.
Eg. Assuming Imin = 2048 ms (Imin has to be base -2 value) and value of k to be 3, Imax is evaluated as Imax = 23 * 2048 = 16384 ms. In short span of time, Trickle algorithm manages topological changes globally. If a node detects any deviation in the reception of DIO message (as in case of a mobile node), timer is set to minimum value i.e. Imin and the DODAG is updated accordingly. Timer moderately increases to Imax in case of stable network. This increased interval may result in low responsiveness of network towards topological changes. As soon as any inconsistency is detected, the timer sets the period to Imin and network gets flooded by DIOs from all the nodes, drastically increasing the network overhead. For discovering any change in the environment, RPL may also use IPV6 Neighbor Discovery algorithm [15]. For 6LoWPAN, an optimized version of neighbor discovery has been developed by IETF[16].

B. IPV6 Neighbor Discovery

This ND algorithm is used for the discovery of new neighbors as well as for detecting the unreachability of a neighbor. ND protocol uses four ICMP's control messages:
(i) Neighbor Solicitation (NS): This message is used to figure out neighbor's link layer address as well as to check the reachability of a neighbor. It is a request message for the delivery of Neighbor Advertisement (NA).
(ii) Neighbor Advertisement (NA): This is a response message to NIS. It is transmitted at regular intervals to reveal any change in the link.
(iii) Router Solicitation (RS): it is appeal by mobile node for information from its router.
(iv) Router Advertisement (RA): It is a response message to RS sent periodically by router specifying its presence along with various parameters and information of the link. To support mobility at network layer of IP based LLN networks, two schemes are categorized depending on the layer on which the routing decision has been taken i.e. adaption layer or network layer [17]. Adaption layer implemented between data link layer and network layer for 6LoWPAN segments and reassembles IPv6 packets.
Difference between Mesh- under routing and Route-over Routing [18] is summarized below in Table1.

IV. LITERATURE REVIEW

A. Mobility Solution for Mesh Under Routing

In [19], author came up with a mobility detection mechanism called LowMOB. In this scheme, detection of mobility depends on repeated transmission of beacons from stationary nodes. Mobile node selects AP with highest RSSI value as their preferred parent. On degradation of link quality with Mobile Node, current AP finds the location of MN by performing localization mechanism with help of mobility support points and new AP starts communicating with MN. LowMOB needs extra hardware for supporting mobility.
For detecting mobility and maintaining the routes, LowMOB requires a lot of packet exchanges (leading to network overhead) and energy consumption. LowMOB is highly responsive to topological changes and minimum single hop hand off delay is approximately 100ms.

In [20, 21], a light version of Mobile IPv6 over 6LoWPAN, called Mobinet is designed by authors. Neighbor Discovery algorithm [15] is used in Mobile IPv6 for detecting any topological changes. In this lighter version, called Mobinet, detection of movement is based on the concept of overhearing in the surrounding of mobile node. As node becomes mobile, its surroundings also change. Router Solicitation RS is generated by mobile node on the detection of any change in the neighborhood. This triggers ND mechanism. Overhearing the neighborhood of mobile node requires processing of extra packets, thereby increasing energy consumption and network overhead. Light Miv6 has high responsiveness as overhearing mechanism listens to activities in the neighborhood of mobile node. As per the authors' conclusion, hand off delay encountered using Light MIv6 is approximately 130ms.

Table 1: Difference between Mesh- under routing and Route-over routing

Metric	Mesh- under routing	Route-over routing
Routing Decision	At Adaption Layer	At Network Layer
Transmission	End to End	Hop to Hop
Delay	Less delay as compared to Route-over routing	Hop by Hop fragmentation and assembly of packets results in more delay
Packet/Fragment Deliver Ratio	Since different fragments of IP packets follow different path, if any fragment is lost during forwarding process, the entire fragments of IP packet are retransmitted.	Better fragment delivery ratio, Low probability of fragment loss.
Transmission Probability	Lower	Higher
Reachability of node	By sending single IP datagram, a node can reach any other node	Only immediate node is reachable within single link transmission

In [16], authors used additional hardware, called proxies, to provide support for mobility. Due to extra hardware requirement, this scheme of network of proxies (NoP) doesn't obstructs normal behavior of network. Proxies invigilate Mobile Nodes for their RSSI values and share this information with other proxies. This RSSI value is used by proxies in selecting next preferred parent for the mobile node. MNs transmit ICMP control packets to proxies at regular intervals. Proxies, in order to maintain the connectivity of network, communicate with each other by managing and enabling hand-offs. This intra-communication among proxies and frequent transmission of control packets from mobile nodes incurs high overhead and consumption of energy. Minimum Hand-off delay observed using NOP is approximately 117ms.

In [22], authors have proposed a location- based mobility support for Intra-6LoWPAN. Hand- off performance is improved by considering both link layer and routing information constructing the route paths without discovering the route. In this approach, mobile nodes are excluded from the process of hand-off. Thus, delay in the hand-off is reduced. This solution has high responsiveness but increases the network overhead due to involvement of extra hardware.

In [23], authors have proposed a mobility solution in which mobile nodes need not to traverse to their home agent in order to move from one router to another. There is no need for COA care of address configuration or address registration in this scheme, thereby reducing the hand off delays for inter and intra-6LoWPAN. An extra hardware is needed in 6LoWPAN to provide location information of nodes without requiring COA configuration. Results conclude that hand off delay for mobility of 5m/s is approx. 30 ms with PLR less than 5%.

Wang et.al [24] proposed a mobility solution for high speed vehicles that implies hand-offs within 6LoWPAN. Through one address configuration operation, each vehicle in vehicle tree architecture is configured with COA. Channel scanning performed at link layer and COA configuration performed at network layer allows each vehicle to independently perform hand off operation. Channel scanning is a time-consuming process. This scheme reduces such delays by offering one channel scanning operation and one address configuration. Hand off delay of nearly 50ms is observed in simulating this proposed technique for various network traffics.

B. Mobility Solution for Route Over Routing

In [25], authors provided support for mobility in RPL by using a fixed Timer. At the cost of increased overhead and energy consumption, network responsiveness is increased by frequent transmission of DIO packets. Updated ETX values are used in the selection of new preferred parent. To avoid loops while selecting new parent, child nodes are not considered in the parent set.

In [26], Korbi et.al used learning algorithm, ME-RPL, to identify mobile nodes. Such identified nodes transmit DIS messages to their neighbors more frequently i.e. less interval of DIS messages. As per the status of network, DIS intervals are adapted dynamically.

Table 2: Inferences drawn from review

Reference	Methods	Approach	Performance Evaluation/Inferences
[21]	Light MIPv6	Mobility detection based on overhearing of nodes using ND algorithm of MIPv6.	High responsiveness on the cost of extra overhead and energy consumption due to overhearing
[19]	LowMob	Mobility detection based on periodic beacon transmission from mobile nodes.	High responsiveness on the cost of additional hardware required for mobility support. High overhead and energy consumption in maintaining mobile routing.
[16]	Network of Proxies	Mobility detection using periodic beaconing in MIPv6	High responsiveness, but periodic signaling between Mobile nodes and proxies results in higher network overhead and energy consumption. Additional hardware required
[22]	Location Based Mobility Solution	Mobility detection based on localization of nodes.	High responsiveness on the cost of additional hardware required and increased network overhead.
[24]	Mobility support in High Speed Vehicles	Mobility detection using periodic beaconing and mobility solution using COA configuration and channel scanning	Reduced hand off delays at the cost of increased network overheads.
[25]	RPL for VANETs	Mobility detection using fixed timers that update the ETX values	High responsiveness. Fixed DIO interval increases overhead in absence of mobility.
[26]	ME- RPL	Mobility detection based on learning algorithm and mobility solution as dynamic DIS interval	Low overhead and energy requirements but low responsiveness in case of sudden environmental changes.
[27]	MoMoRo	Mobility detection based on loss of packets during run time, followed by immediate broadcasting of beacons	Being a passive approach, it is low responsive to topological changes. Improved PDR as compared to default-RPL
[28]	mod-RPL	Uses Trickle timer algorithm of periodic beaconing for detection of mobility	Dynamic DIS interval leads to low responsiveness. This approach has less packet overhead and hand-off delays.
[29]	KP-RPL	Mobility detection uses Kalman Filtering to predicts position of nodes	Low Responsiveness and high processing overhead
[30]	Corona-RPL	Mobility Detection using Corona localization technique that determines position of nodes	Increased PDR, decreased Energy Consumption. Errors in localization techniques propagate from one location to another.
[6]	mRPL+	Mobility Detection with help of timers and ICMP packets	High Responsiveness. Soft hand off requires overhearing.

Learning algorithm can guess only regular disconnections, instant mobility is missing in ME-RPL resulting in low responsiveness to sudden topological changes. The nodes explicitly advertise their status of mobility info via control messages, thereby enabling the nodes to differentiate between static nodes and mobile nodes. These static nodes are eligible candidates for becoming preferred parent of mobile nodes, avoiding routes through moving nodes. DIS messages (that is basically used in RPL for discovering new neighbors during construction of new network) are used to keep a check on the stability of environment. The interval of DIS messages is controlled by an external mechanism that takes into account the neighborhood stability.

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In [27], author proposed mobility support for low traffic network, dubbed as MoMoRo. Packet loss encountered during run time is considered as detection mechanism of mobility. Being a passive approach, it has low responsiveness to changes in topology aroused due to mobility of nodes. Packet loss may also be caused due to link degradation in low power networks, hence performing hand-offs based on packet loss may incur network overhead due to needless maintenance of route.

In [28], author presented mod-RPL that takes into account path and velocity of mobile nodes to accommodate Trickle timer dynamically. In construction of network topology, DIS messages are broadcasted by routers to their neighbors which are replied as DIO messages. This DIO message from neighbors help router to choose their best-parent depending on rank, which is evaluated using ETX and RSSI values. DIO interval for mobile node is based on its distance from the preferred parent. Results in simulation show that mod-RPL less hand off delay and packet overhead.

In KP-RPL [29], Kalman positioning RPL strategy is presented to support mobile nodes. By evaluating velocity estimates, Kalman filter increases the accuracy of prediction of positioning of mobile nodes. A confidence area is created for each mobile node which includes the most likely position of nodes. Along with that, a list of unreachable node is also generated for each mobile node. The best path is selected depending on the end to end ETX values. Simulation results show improved performance of network reliability in hard environment. However, the main drawback of this work is the lack of realistic simulation and experiments. However, due to high processing overheads, implementation of Kalman filtering is difficult in dynamic network having mobile nodes where there is need of high responsiveness.

In [30], author proposed expanded RPL- Corona-RPL (Co-RPL) that has provision for mobility of nodes. Keeping the track of location of moving nodes improves the performance of network. It uses Corona localization technique to determine the position of mobile node. Coronas refer to the circular area in the vicinity of various DAG roots, in which the network is divided by the mechanism. The location of the nodes is computed by this proposed extension depending on their gap from the DAG roots. With each router as center, network is divided into circular regions called Coronas. DODAG root sends DIOS to estimate the location of mobile nodes, period of which is dependent on the speed value of node. However, drawback of this technique is the erroneous nature of localization techniques in which error propagates further from one location to the other.

C. Multipath Routing over RPL

Multipath routing protocols used in WSNs [31] and Adhoc Networks [32] provide load balancing, congestion-avoidance, fault tolerance and QoS. There are two types of multipath routing techniques: Disjoint Multipath Routing: In this scheme, each route comprises of different links/nodes. Being totally independent path, failure of any path have no effect on any other path. In disjoint routing, global information of topology is required to maintain all alternative paths which results in high consumption of energy.

Braided Multipath Routing: In this scheme, for each node n, substitute paths are established that doesn’t contain n in the path. As these paths overlay with primary paths, lesser energy is needed in development of such alternative paths. To reduce latency and increase the reliability of network, Congestion Avoidance-RPL (CA-RPL) is proposed by authors in [33]. CA-RPL introduced a new metric depending on ContikiMAC duty cycle, called Delay Root. Rather than sending packets to preferred parent and waiting for them to wake up, nodes transmit packets to already awake parents. To minimize delay and control congestion, data is dispatched on different paths. The new metric introduced assumes wake up time interval for all nodes to be same.

D. Updating of Old Route Cancellation

In [13] rather than concentrating on choosing the parent efficiently, author introduces an upgraded route-elimination algorithm in which no-path DAO are generated by parent common in new and old path. Firstly, the transmission of DAO is not delayed by the mobile nodes. Secondly, rather than mobile nodes, no-path DAO are generated by the common ancestor after receiving an updated DAO. This common ancestor propagates the no-path DODAG towards older downwards route and older parent of moving node. Advantages: Since new route is established with new parent using DAO before demolishing the older path, nodes between common ancestor and mobile node and still communicate with mobile node till new route is constructed. Secondly, as no-path DAO in this mechanism are generated by common ancestor and not by the mobile node, the inconsistent state resulting due to loss of no-path DAO (initiated by Mobile Node) never occurs. However, if in case mobile node moves from one DODAG to another, this concept of common ancestor might not come into play. Moreover, since no-path DAO is generated by common ancestor, there might be delay in propagation of updating information resulting in packet loss through invalid route.

Alternative Solutions:

1. Transmission of np-DAO only after the transmission new DAO message communicated by mobile node for development of new path. Advantage: Delay in propagation of these route cancellation np-DAO messages guarantees the existence of downward path to the moving node. Disadvantage: This solution increases probability of older parent being unreachable and inadequate to receive np- DAO, leading to the formation of inconsistent path.

2. Instead of propagation of np-DAO having lifetime zero from moving node to older parent, transmission of DAO packets with confined timespan. Older path gets deleted only after the expiry of this time period. Advantage: Downward route gets a prior information regarding demolishing of route, thereby enabling them to decide different possible routes within that lifetime of path defined. This reduces packet loss due to packet transmission on invalid route. Disadvantage: Path becomes inconsistent if in case the mobile node becomes unreachable within this defined/bounded lifetime period. (ii) The mobile node may reach in a situation of having no path if new parent is out of reach due to improper selection of parent and old path has its validity expired.

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V. INFERENCES DRAWN

Table 2 summarizes the inferences drawn from papers reviewed.

VI. CONCLUSION

Variations in the environments caused due to electromagnetic noise, humidity, temperature intend the researches in Low-Power Wireless Networks (LPWNs) to assume the network with different topological conditions. To provide better network connectivity, distributed mobility management is required in IOT applications. The main challenge in Low Power and Mobile Network is to provide Quality of Service along with the support of mobility. This paper discusses the challenges in mobility support required for RPL as well as various areas open for improvement in RPL, like route selection, route establishment deferring, loop avoidance etc. A scheme that handles nodes mobility effectively and efficiently with minimum delay in hand offs is still an open area of research. Variations in the environments caused due to electromagnetic noise, humidity, temperature intend the researches in Low-Power Wireless Networks (LPWNs) to assume the network with different topological conditions. To provide better network connectivity, distributed mobility management is required in IOT applications. The main challenge in Low Power and Mobile Network is to provide Quality of Service along with the support of mobility. This paper discusses the challenges in mobility support required for RPL as well as various areas open for improvement in RPL, like route selection, route establishment deferring, loop avoidance etc. A scheme that handles nodes mobility effectively and efficiently with minimum delay in hand offs is still an open area of research.

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