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Research Article

Optimizing IoT Network Performance: A Review of Contemporary Routing Protocols

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ABSTRACT

Introduction: The large-scale application of IoT devices transforms the diverse facets of living. Currently, a wide variety of IoT-based applications are developed and executed. IoT includes interconnected objects embedded with sensors interacting with other objects and humans.

Objectives: These objects can sense, monitor the surroundings, and transform that information. IoT increases the utility of the Internet by incorporating devices for collaboration using embedded systems that lead to an extremely distributed collection of devices cooperating with humans in addition to other devices.

Methods: With rapid advances in primary technologies, IoT incredible chances for a huge number of applications that promise to improve the excellence of societies including the mobility of the device.

Results: Consequently, facing several challenges like ensuring security, efficient routing, energy efficiency, and effective resource allocation are in the implementation of IoT and MIoT-based networks.

Conclusions: In this paper, diverse routing protocols designed for of IoT and MIoT-based networks are discussed in detail.

Keywords: Routing protocols, RPL, AODVng, Context-aware, Energy aware.

INTRODUCTION

Recently, the Internet of Things (IoT) is an engaging area of research. Considering that industry, transportation, agriculture, smart city as well as healthcare are the predominant application areas. Based on its characteristics, capacity to sensing, monitoring the surroundings, and transforming that information to other devices, interact with each other through the functioning of an IP dependent network. Each device is considering as a node. The nodes are proficient in collaborating among themselves to attain a goal. The natural characteristics of IoT based on WSN, it doesn't have IP address like IPV4 and IPV6. it only has a unique identification number for each device. it could not enough to connect each device in the globe. consequently, Internet Engineering Task Force (IETF) has taken considerable efforts specific for IoT include IP-dependency, global addressing and large-scale deployment.

IoT has drawn much interest of the scientific community as well as business segment for the excessive research and business chances. Nevertheless, besides the advantages of IoT arise practical challenges of prevailing technological restrictions. The devices are small and encounter several restrictions including processing, memory and energy. The devices may be mobile that harden network functioning [1].

In IoT, routing protocols are accountable for offering routes and sending packets amid the linked devices. LLNs, comprising energy-constrained nodes and one or more routers known as Gateways(GW), are characterized by low power and lossy networks.

The nodes may communicate directly with the GW or through intermediary nodes. This is dealt by the routing protocols which are involved in distributing data from a node to GW. Routing protocols should be simple and execute proficiently in any device with least computational cost. Besides device level performance, the routing protocols should be capable of adapting to the typological deviations produced by device mobility [2]. IETF uses Routing Protocol for Low-Power and Lossy Networks (RPL) which facilitates in defining routing policies based on the preference about network demands and metrics [3].

RELATED WORK

There is a thorough discussion of the routing systems proposed by different scholars. Energy-Aware Routing in IoT, Load-Balanced Routing, Bio-inspired, RPL-based Routing, Context-Aware Routing, and Lightweight On-Demand Ad Hoc Distance Vector Routing for Next Generation are the topics covered in this review paper. Below is a detailed discussion of each direction along with its current features and contributions.

Energy-Aware Routing in IoT

Park et al (2014) [4] have propounded Energy-Efficient Probabilistic Routing (EEPR) algorithm that focusses on the broadcast of RREQ packets to improve network lifespan and lessen packet loss during flooding. The proposed model uses energy-proficient probabilistic control by concurrently using residual energy of every node along with the Expected Transmission Count (ETX) in AODV protocol. It is seen that the proposed algorithm offers increased network lifespan and devours uniform amount of remaining energy in every node in contrast to AODV protocol.

Nguyen et al (2017) [5] have designed Energy-Harvesting-Aware Routing Algorithm (EHARA) for varied WSN-dependent IoT applications using ambient energy sources. The propounded routing scheme called EHARA is improved by incorporating a factor called 'extra backoff'. The scheme enhances Quality of Service (QoS) and lifespan of nodes for varying traffic loads and energy availability. The proposed algorithm outdoes the prevailing Randomized Minimum Path Recovery Time (R-MPRT) algorithm based on network lifespan. The lifespan is improved in contrast to the Energy Harvesting Aware Ad-hoc On-Demand Distance Vector Routing Protocol (AODV-EHA) algorithm. Figure 1 shows the simple architecture of energy-aware routing protocol.

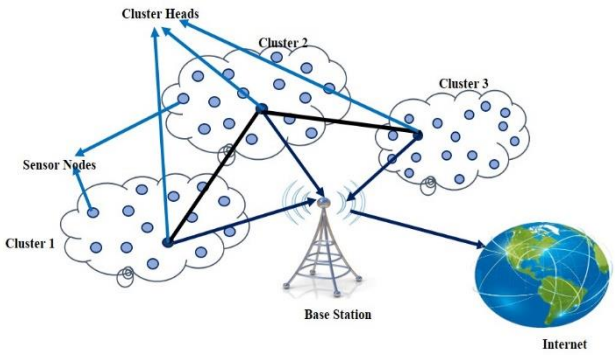

Figure 1: Architecture of Energy aware routing protocol

Wang et al (2018) [6] have propounded an energy-effective clustering and routing scheme. Non-uniform distribution of traffic is considered, and an irregular cluster construction mechanism for balancing load and ensuring energy efficiency is proposed. A non-centralised Cluster Head (CH) rotation scheme to stabilise energy in every cluster is designed. To support long distance transmission, a dynamic multi-hop routing scheme amid CHs using distance as well as energy-based cost function to circumvent energy hole problem is proposed. The proposed algorithm offers better network lifespan, throughput as well as energy efficiency.

Energy consumption in a node is to be checked for enhancing the global network performance by applying Machine Learning (ML) schemes and making efficient routing choices. Several schemes are available to support energy effective routing. Improved versions of the same are required for applying them in IoT environment. A Neuro-Fuzzy Rule based Cluster Formation and Routing Protocol is proposed by Thangaramya et al (2019) [7] to support effective routing. The propounded scheme is seen to conserve energy, offer better Packet Delivery Ratio (PDR) and improve network lifespan with reduced delay.

Sankar & Srinivasan (2018) [8] have propounded a cluster dependent energy based protocol for LLNs with multiple layers that splits network into several rings with identical lengths. Intra-ring clustering breaks a ring into clusters of same size and routing amid clusters uses Fuzzy Logic (FL) to choose an efficient path for transferring data. The network lifespan along with PDR is improved.

Preeth et al (2018) [9] have presented dynamic Fuzzy rule based Energy Efficient Clustering and Immune-Inspired Routing (FEEC-IIR) protocol designed for WSN supported IoT based network. For ideal CH selection, Adaptive Fuzzy Multi-Criteria Decision Making (AF-MCDM) scheme is utilised that is a blend of fuzzy AHP as well as TOPSIS. Energy, QoS and node position are considered as chief factors which can influence the selection of CHs, whereas every criterion includes certain sub-criteria. Immune-stimulated optimization scheme for routing is used for enhancing consistency of data delivery. Cluster based routing reduces energy consumption. From the outcomes, it is seen that the proposed scheme enhances QoS factors including network lifespan, PDR, Bit Error Rate (BER), jitter, Packet Loss Ratio (PLR), throughput, delay, load, buffer tenancy and energy in contrast to the prevailing clustering and routing methods.

Sankar & Srinivasan (2018) [10] have propounded a FL based Energy Aware Routing Protocol (FLEARPL) that takes load, remaining energy as well as ETX into consideration for choosing routes. FLEA-RPL involves FL to choose the finest path to transmit data proficiently. COOJA simulator is employed for assessing the competence of the propounded scheme. The proposed protocol's performance is analysed along with MRHOF based RPL (MRHOFRPL), FL-RPL and RPL based on network lifespan and PDR.

Debroy et al (2019) [11] have propounded Spectrum aware Energy-Efficient multi-hop multi-channel routing for D2D communication (SpEED-IoT) in IoT based mesh network. Information related to Radio Environment Map (REM) is got using devoted spectrum sensors which deal with the spatio-temporal spectrum. REM is used to design a multi-hop routing mechanism which determines the finest route, existing channels in each hop along the path and ideal transmission power for each hop. It uses game theoretic path assignment model to manage parallel D2D communication. The scheme guarantees approved incumbent protection, device energy conservation, efficient data rate optimization, fast convergence and fair route allotment amid intrusive D2D communications. The performance is assessed using simulation-driven GENI-dependent IoT testbed based on connectivity as well as reachability amid IoT devices in changing spectrum usage, data rate optimization of allocated paths and complete network, efficiency in approved mandatory protection and fairness level while allocating paths to several devices.

Dhumane & Prasad (2019) [12] have propounded a fractional gravitational search with multiple objectives to determine ideal CH for energy effective routing. To improve node lifespan, Fractional Gravitational Search Algorithm (FGSA) is propounded to determine the ideal CH iteratively in network. The CH is chosen which is assessed by the Fitness Function (FF) using several purposes like link lifetime, distance, delay and energy called Multi-Objective FGSA (MOFGSA). The performance is assessed in contrast to standard algorithms. The propounded MOFGSA scheme guarantees to extend the lifespan of nodes.

Safara et al (2020) [13] emphases on the amount of energy, where Priority-based and Energy efficient routing (PriNergy) scheme is propounded. The scheme depending on RPL model finds routing based on contents. Every network slot involves timing patterns while forwarding data taking audio as well as image related data. The scheme improves the sturdiness of protocol and eventually avoids congestion. The proposed scheme decreases the overhead on mesh, delay and amount of energy. Furthermore, it outdoes the Quality of Service RPL (QRPL).

Jaiswal & Anand (2020) [14] have designed energy-proficient routing protocol for WSN based IoT application with increased lifetime, trustworthiness and traffic intensity at the ensuing node. The propounded protocol is analysed with other modern protocols. The outcomes reveal that the propounded protocol offers improved results related to energy, PDR, delay and network lifespan in contrast to other protocols.

Energy preservation is challenging to extend network lifespan in IoT. Sankar et al (2020) [15] have proposed an Energy-Aware Multipath Routing Protocol (EAM-RPL) to improve lifespan of network. The multi-path model forms numerous routes from source to sink. Randomised network coding is applied at the source to encrypt packets and transmit them to the ensuing level of clusters. The intermediary nodes obtain the encrypted packets and send them to ensuing cluster. Lastly, the sink obtains them and decrypts the original packets. The results of EAM-RPL are compared with RPL.

Owing to massive diverse data from several sensing devices, IoT-based WSNs are open to diverse challenges based on delay, network lifespan and throughput. Deep-Reinforcement-Learning (DRL)-dependent routing mechanism is propounded by Kaur et al (2021) [16] for IoT-based WSNs which considerably decreases delay and improves network lifespan. The propounded mechanism splits the entire network into diverse uneven clusters depending on the present load which considerably avoids early network death.

Iqbal et al (2022) [17] have propounded energy energy-aware zone-based routing scheme that uses game theory to improve cooperation amid nodes and energy efficacy. Paths with maximum mean energy for communication and cooperative support increase network lifespan. It is seen that the propounded scheme offers improved throughput, PDR, and network lifespan. Table 1 shows the details of Energy Aware Routing Schemes in IoT.

Table 1: Energy Aware Routing Schemes in IoT

Authors	Mechanism	Merits
Park et al (2014) [4]	Energy-Efficient Probabilistic Routing (EEPR) algorithm	Offers increased network lifespan consuming uniform amount of remaining energy
Nguyen et al (2017) [5]	Energy-Harvesting-Aware Routing Algorithm (EHARA)	Offers improved lifespan
Wang et al (2018) [6]	Energy-effective clustering and routing scheme	Offers better network lifespan, throughput as well as energy efficiency.
Thangaramya et al (2019) [7]	A Neuro-Fuzzy Rule based Cluster Formation and Routing Protocol	Conserves energy, offers better Packet Delivery Ratio (PDR) and improves network lifespan with reduced delay
Sankar & Srinivasan (2018) [8]	Cluster dependent energy based protocol for LLNs with multiple layers	Improves network lifespan along with PDR
Preeth et al (2018) [9]	Dynamic Fuzzy rule based Energy Efficient Clustering and Immune-Inspired Routing (FEEC-IIR)	Enhances QoS factors including network lifespan, PDR, Bit Error Rate (BER), jitter, Packet Loss Ratio (PLR), throughput, delay, load, buffer tenancy and energy
Sankar & Srinivasan (2018) [10]	FL based Energy Aware Routing Protocol (FLEARPL)	Improves network lifespan along with PDR
Debroy et al (2019) [11]	Spectrum aware Energy-Efficient multi-hop multi-channel routing for D2D communication (SpEED-IoT)	guarantees approved incumbent protection, device energy conservation, efficient data rate optimization, fast convergence and fair route allotment
Dhumane & Prasad (2019) [12]	Fractional Gravitational Search Algorithm (FGSA)	Improves link lifetime, distance, delay and energy
Safara et al (2020) [13]	Priority-based and Energy efficient routing (PriNergy) Scheme	improves the sturdiness of protocol and eventually avoids congestion
Jaiswal & Anand (2020) [14]	Energy-proficient routing protocol	improves energy, PDR, delay and network lifespan
Sankar et al (2020) [15]	Energy-Aware Multipath Routing Protocol (EAM-RPL)	Improves lifespan of network
Kaur et al (2021) [16]	Deep-Reinforcement-Learning (DRL)-dependent routing mechanism	Decreases delay and improves network lifespan
Iqbal et al (2022) [17]	Energy aware zone-based routing scheme that uses game theory	Offers improved throughput, PDR and network lifespan

Load-Balanced Routing in IoT

Owing to resource restraints at nodes and untrustworthiness of links, single-path routing is not efficient in determining the needs of several applications. To deal with these issues, several researches emphasis on multi-path solution for RPL routing. Le et al (2014) [18] have propounded 3 multi-path mechanisms depending on RPL namely, Fast Local Repair (FLR), Energy Load Balancing (ELB) as well as ELB-FLR and incorporate them in an altered IPv6 communication stack. The mechanisms are implemented using OMNET++ simulator. It is seen that the proposed scheme offers better energy, improved end-to-end delay, PDR and load balance in contrast to conventional RPL.

To increase throughput, several wireless technologies like Parallel Opportunistic Routing (POR) is used for parallel data transmission. In POR, data from a GW to internet always takes similar path. This causes congestion in particular GWs that affects Throughput. A dynamic and load balanced routing scheme named Adaptive Routing using Multi-technology and Load balancer (ARMY-Lancer) is proposed by Kotagi et al (2017) [19] for improving throughput by allocating load. The propounded mechanism offers better throughput and mean load across GWs.

With dynamic and increased user demands, it is essential to improve energy efficiency while guaranteeing performance and service quality. Energy consumption model that depends on link loads as well as network's bit energy depletion to determine energy efficacy is proposed. To reduce bit energy consumption, a routing scheme that incorporates energy efficient routing as well as load balancing is propounded by Roy et al (2018) [20]. To enhance energy efficacy of a network, Energy-Efficient Multi-Constraint Re-Routing (E2MR2) algorithm is proposed. It involves an energy consumption model to establish link weight for improved energy efficacy and exploits re-routing to guarantee QoS and increased delay restraints. The proposed scheme offers better results.

Sankar & Srinivasan (2018) [21] have dealt with improving the network lifespan which is a challenge in LLNs. Routing plays a dominant role in dropping the amount of energy consumed across networks by selecting routes efficiently. IPv6 Routing Protocol for RPL is an IETF consistent protocol developed for LLN. In Energy and Load aware RPL (EL-RPL) protocol, enhanced RPL is proposed. A compound metric computed depending on ETX, Load as well as Battery Depletion Index (BDI) is used for selecting paths. EL-RPL's performance is compared with RER RPL and OF-FL based RPL (OF-FL RPL).

Dropping the quantity of energy spent is obviously vital to prolong the network lifespan. Agrawal & Pandey (2020) [22] have proposed a fuzzy-dependent unequal clustering protocol. The proposed protocol extends network lifespan and balances load amid nodes. Existing protocols do not focus on balancing loads. FL which considers the remaining energy, distance to the BS, degree of nodes as well as centrality is used. To ensure efficacy, the protocol is associated with benchmarked protocols. The outcomes demonstrate that the protocol outdoes other protocols.

Adil (2021) [23] has proposed an effective lightweight routing protocol for load balancing to deal with the challenges in IoT networks. Dynamic Hop Selection Static Routing Protocol (DHSSRP) is propounded to deal with load balancing in congestion-less and priority-dependent infrastructure. The propounded protocol gives priority to sensitive information with static routing and turns away the neighbour's communiqué with an alternating hop selection route that organises traffic in congestion-less setting. Traffic organization of DHSSRP routing protocol depending on priority-dependent data stabilises energy consumption which improves the lifespan of the positioned devices. The outcomes for the proposed mechanism are compared with the benchmarked mechanisms that show a considerable improvement based on communication and computational costs, traffic congestion, PLR, throughput and network lifespan. Table 2 gives the details of Load Balanced Routing Schemes in IoT.

Table 2: Load Balanced Routing Schemes in IoT

Authors	Mechanism	Merits
Le et al (2014) [18]	Multi-path mechanisms depending on RPL - Fast Local Repair (FLR), Energy Load Balancing (ELB) as well as ELB-FLR	Offers better energy, improved end-to-end delay, PDR and load balance
Kotagi et al (2017) [19]	Adaptive Routing using Multi-technologY and Load balancer (ARMY-Lancer)	Offers better throughput and mean load across GWs
Roy et al (2018) [20]	Energy-Efficient Multi-Constraint Re-Routing (E2MR2) algorithm	Improves energy efficacy and exploits re-routing to guarantee QoS and increased

		delay restraints
Sankar & Srinivasan (2018) [21]	Energy and Load aware RPL (EL-RPL) protocol	Improves the compound metric computed depending on ETX, Load as well as Battery Depletion Index (BDI)
Agrawal & Pandey (2020) [22]	Fuzzy-dependent unequal clustering protocol	Remaining energy, distance to the BS, degree of nodes as well as centrality
Adil (2021) [23]	Dynamic Hop Selection Static Routing Protocol (DHSSRP)	Improves communication and computational costs, traffic congestion, PLR, throughput and network lifespan

Bio-Inspired Routing in IoT

Said (2017) [24] has proposed a routing scheme that deals with optimised choice of the finest route for communicated data within IoT network. The algorithm employs ACO based concepts to get the finest routing. It splits the environment into regions based on network kinds. ACO algorithm is applied on the network in every region. Moreover, the algorithm deals with the routing problem in interconnected regions which arises in an IoT-based network.

Communications related factors and restraints should be considered during routing. Hamrioui & Lorenz (2017) [25] have surveyed a number of routing algorithms for effectual communication within wireless networks and IoT. To overcome the demerits of the existing works, Efficient IoT Communications based on Ant System (EICAntS) is propounded to improve route selection by using the merits of ACO algorithm. The proposed scheme offers better lifespan, throughput, delay as well as reduced energy.

Almazmoomi & Monowar (2019) [26] have suggested a Bee-Inspired Routing Algorithm (BIRA) for supporting D2D communication. It is an on-demand routing scheme which mimics bee's searching behaviour model to find the ideal path amid the source and destination to provision communication in multi-hop fashion. The outcomes of the proposed BIRA are evaluated based on PDR, energy, network lifespan as well as delay.

To deal with the present issue of co-operative node movement, dropping initialization time for ant dependent routing and maintaining scalability in time-critical applications, an ACO based routing scheme is propounded and analysed by Sharmin (2019) [27]. Energy factor is used along with mean node mobility to determine the probability of an ACO that is a unique factor used in the design of Ant scheme in contrast to the existing work and construction of mathematical model. A FF, path evaluation index is offered for ideal route selection by considering the prevailing node energy and path length. The proposed scheme is simulated using MATLAB and assessed against conventional ACO and EICAntS scheme. The assessment outcomes of the propounded ACO based algorithm achieves quicker convergence of initialization delay, offers enhancements to determine the finest route, decreased delay and energy with growing number of nodes in contrast to other algorithms and validates an upgrading in preservation of energy, throughput, delay and lifespan.

To diminish the quantity of energy involved in an IoT network, a smart routing mechanism is demanded. Sackey et al (2020) [28] have proposed routing scheme that uses bio-inspired technique to prolong network lifetime. Knowledge discovery helps in determining the proficient path for effective routing. Anonymous directions to enhance smart routing are found. Nevertheless, the bio-inspired scheme takes the impact of human idea by determining knowledge and uses distance as well as energy to define the FF. The function keeps more number of nodes alive, delivers packets and preserves energy. The proposed scheme outperforms the present routing techniques depending on remaining energy, PDR and network lifespan.

Saad et al (2021) [29] have propounded a routing scheme which deals with prolonging the network lifespan and preserve the nodes' energy. The hybrid algorithm depending on Genetic Algorithm (GA) as well as Ant Colony Optimization (ACO) algorithms is proposed, while GA is employed in choosing the effective CH. The FF of GA takes the distance as well as energy factors while choosing CHs. ACO is involved in data transmission. Moreover, distance as well as energy is considered while selecting the finest route to forward data to Base Station (BS) from CH. This hybrid algorithm is assessed against Improved LEACH as well as GA-PSO algorithms. The propounded scheme

offers improved network lifespan, conserves energy and extends the network lifespan in contrast to the benchmarked algorithms.

Pingale & Shinde (2021) [30] have propounded routing protocol depending on Sun Flower based Grey wolf optimization (SFG) for enhancing network lifespan. Multi-path routing is introduced and SFG scheme chooses the finest path from multi-path for routing depending on context awareness, remaining energy, trust, network lifespan and delay. Lastly, multi-path routing in network is used to choose ideal path using the propounded SFG algorithm. SFG integrates Sun Flower Optimization (SFO) as well as Grey Wolf Optimizer (GWO).

Tandon et al (2021) [31] have proposed a Bio-inspired Cross-Layer Routing (BiHCLR) protocol to attain efficient and energy conserved routing. Firstly, the sensors are organised as a grid. Energy conservation is achieved in BiHCLR, where FLis used to choose the CH in each grid cell. A hybrid bio-inspired scheme is employed in choosing routing paths. The algorithm is an amalgamation of Moth search and Salp Swarm optimization schemes. The performance is assessed based on network lifespan, packet loss, delay, error bit rate, buffer occupancy and throughput. The performance is found to be better in contrast to several benchmarked schemes. Table 3 gives the details of Bio-Inspired Routing Schemes in IoT.

Table 3: Bio-Inspired Routing Schemes in IoT

Authors	Mechanism	Merits
Said (2017) [24]	Routing scheme that deals with optimised choice of the finest route	Offers Optimised routing
Hamrioui & Lorenz (2017) [25]	Efficient IoT Communications based on Ant System (EICAntS)	Improves lifespan, throughput, delay as well as reduced energy
Almazmoomi & Monowar (2019) [26]	Bee-Inspired Routing Algorithm (BIRA)	Improves PDR, energy, network lifespan as well as delay
Sharmin (2019) [27]	ACO based routing Scheme	Achieves quicker convergence of initialization delay, offers enhancements to determine the finest route, decreased delay and energy
Sackey et al (2020) [28]	Routing scheme based on bio-inspired technique	Improves remaining energy, PDR and network lifespan
Saad et al (2021) [29]	Hybrid algorithm depending on Genetic Algorithm (GA) as well as Ant Colony Optimization (ACO)	Offers improved network lifespan, conserves energy and extends the network lifespan
Pingale & Shinde (2021) [30]	Sun Flower based Grey wolf optimization (SFG)	Offers better results based on context awareness, remaining energy, trust, network lifespan and delay
Tandon et al (2021) [31]	Bio-inspired Cross-Layer Routing (BiHCLR) protocol	Improves network lifespan, packet loss, delay, error bit rate, buffer occupancy and throughput

RPL based Routing in IoT

ETX in RFC 6551 is widely used Minimum Rank with Hysteresis Objective Function (MRHOF) metric. It aids in achieving improved PDR and reduced latency since particles select to transmit data along the route with reduced amount of retransmissions. As ETX does not take into consideration the level of energy of motes, the amount of energy consumed amid motes is not balanced. Banh et al (2016) [32] have developed routing metrics by considering the amount of energy consumed at the motes as the routing metric. Radio Duty Cycle (RDC) based scheme is developed to measure the amount of energy at the mote. Blends of ETX as well as energy are considered as routing metrics. The proposed scheme offers improved energy balance while maintaining better energy efficacy and PDR. Figure 2 shows the topology for RPL based routing protocol.

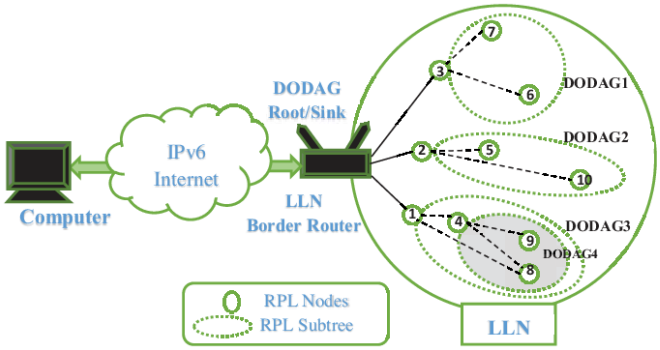

Figure 2: RPL Topology

FL involved in unicasting is effective. It fails to deal with the substantial metrics which is essential. Aljarrah (2017) [33] has addressed the use of RPL by offering an OF depending on FL. QoS is built using Destination Oriented Directed Acyclic Graph (DODAG) which plays a dominant role. The OF is attained using Multi-FL (Ml-FL) model that incorporates 3 important classes of metrics like node, channel as well as link based metrics. Ml-FL proves the use of 9 metrics to select the finest parent for unicast. The metric is defined using 3 factors for selecting efficient parent node. Several FL blocks are propounded. An improved-BMRF algorithm is designed with reduced delay as well as the amount of duplicate packets. The system is implemented using OMNeT++ simulator and the system is analysed based on hop count, delay, energy, PDR and PLR.

When RPL is utilised in LLNs, some nodes undergo congestion and this strictly reduces performance. Parsaei et al (2017) [34] have dealt with considering solutions provided to handle load balancing issues. Load balancing protocols like IETF-RPL and LB-RPL is implemented using COOJA simulator. Parameters like mean delay, PDR and Throughput are assessed. LB-RPL offers increased PDR as well as throughput. It involves more delay.

When a router fails, inaccessible destinations may be certainly formed owing to absence of memory to save a routing entry in the related sub-network. Specifying Downward Advertisement Objects (DAOs) to a smaller extent is another challenge in RPL. When and how frequently DAOs are to be produced is not dealt with leading to incompetent implementations. Ghaleb et al (2017) [35] have presented a better form of RPL called Enhanced-RPL. To alleviate the issue of storage restriction of node's favoured parent, a node is permitted to allocate prefixes fitting to the sub-network amid several parents. More watchful method for producing DAOs is offered to alleviate the challenge of DAOs. The proposed scheme outdoes RPL based on control plane overhead and PDR.

RPL is used in building a Destination Oriented Direction Acyclic Graph (DODAG) to establish topology. It suffers from load unevenness owing to varied traffic and increased load on favoured or advancing parents. To deal with load balancing, Sebastian & Sivagurunathan (2018) [36] have proposed load balancing based Routing ProtocoL (lbRPL). Load Balancing Index (LBI) is used to implement features of nodes to choose more number of parents as well as routes. The LBI comprises of ETX, count of parents and remaining energy at the parent for making routing choices. It is seen that lbRPL offers better performance, stability and network lifespan.

Kharrufa et al (2019) [37] have presented the chief features of RPL along with the benefits and drawbacks of using RPL in diverse applications. The existing research associated with RPL is detailed and protocols are assessed based on energy efficacy, trustworthiness, flexibility, sturdiness and security.

Almusaylim et al (2020) [38] have reviewed on the present research, chances and investigation gaps of safe RPL based routing protocols taking rank as well as version number attacks kinds into consideration. The review details the demands for a safe RPL protocol to deal with security challenges of smart city applications predominantly depending on the existing literature.

Idrees & Witwit (2021) [39] have propounded Energy-efficient Load-balanced RPL (EL-RPL). The proposed protocol deals with choosing parents. It chooses parent from the list as the ensuing hop node to the destination depending on an Objective Function (OF) which combines increased residual energy and total amount of packets received at the parent. This balances load on parents in list. The proposed protocol enhances DODAG building by avoiding DIO transmission packets to nodes with reduced ranks. This conserves energy and improves networks'

lifespan. The system is simulated using OMNeT++ to assess the efficacy of propounded protocol. The propounded protocol conserves energy, reduces the number of control packets and improves network lifespan.

Nodes, sinks as well as GWs are heterogeneous, and have restricted resources and demand substantial cost as well as installation time. Virtual Sensing Networks (VSNs) play a significant role in facilitating creation of virtual groups which associate desirable detection as well as routing resources. Sensing Resource Allocation with Dynamic Resource-Based Routing (SRADRR) is proposed by AlShiab et al (2021) [40]. SRADRR scheme constructs the present distinguished authorisation of networks involving RPL as well as 6LowPAN. The propounded scheme employs RPL to build DODAG routing trees which adjusts based on the accessible identifying resources as well as demands of running applications. The proposed scheme offers improved deployment rate. Table 4 summarises the details of RPL based Routing Schemes in IoT.

Table 4: RPL based Routing Schemes in IoT

Authors	Mechanism	Merits
Banh et al (2016) [32]	Radio Duty Cycle (RDC) based scheme	Offers improved energy balance while maintaining better energy efficacy and PDR
Aljarrah (2017) [33]	OF depending on FL	Reduces delay as well as the amount of duplicate packets
Parsaei et al (2017) [34]	Solutions provided to handle load balancing issues	Offers better PDR and Throughput with reduced delay
Ghaleb et al (2017) [35]	Enhanced-RPL	Reduces control plane overhead and improves PDR
Sebastian & Sivagurunathan (2018) [36]	load balancing based Routing ProtocoL (lbRPL)	ETX, count of parents and remaining energy, stability and network lifespan
Kharrufa et al (2019) [37]	Features of RPL along with the benefits and drawbacks of using RPL	Improves energy efficacy, trustworthiness, flexibility, sturdiness and security
Almusaylim et al (2020) [38]	Reviewed on the present research, chances and investigation gaps of safe RPL based routing protocols	Deals with security challenges of smart city applications
Idrees & Witwit (2021) [39]	Energy-efficient Load-balanced RPL (EL-RPL)	Conserves energy, reduces the number of control packets and improves network lifespan
AlShiab et al (2021) [40]	Sensing Resource Allocation with Dynamic Resource-Based Routing (SRADRR)	Offers improved deployment rate

Context-Aware Routing in IoT

Chen et al (2012) [41] have dealt with sea computing model in IoT and routing protocol of WSN. Context-Awareness in Sea Computing Routing Protocol (CASCR) is proposed which depends on context-awareness belonging to key technologies of IoT. The protocol along with data structure and quantifiable algorithm are detailed. The performance of the propounded protocol is analysed depending on energy efficiency and lifespan.

Kalmar et al (2015) [42] have contributed Context-Aware Addressing and Routing mechanism (CAEsAR). It involves RPL trees and gathers context information from Bloom-filters in the tree. The performance of CAEsAR is compared with TRENDY and MQTT-SN. CAEsAR produces lesser signalling traffic during RPL tree formation stage and system adaptation to variations of context factors.

Chen et al (2018) [43] have detailed Agricultural LLNs (A-LLNs) and have mentioned about the demands of the application-based routing algorithm. They have reviewed the prevailing optimization schemes for RPL, and have

contributed Scalable Context-Aware Objective Function (SCAOF) which can adjust RPL to environmental observing of A-LLNs by linking energy, robustness, resource and trustworthiness based contexts depending on the compound routing metrics. The precise nature of the improved RPL (RPAL) is confirmed by evaluating performance. SCAOF offers better network lifespan, increased trustworthiness and efficacy in diverse scenarios and testbeds.

Biason et al (2017) [44] have propounded an energy and context-based architecture that deals with the influence of energy on the basic functionalities of an IoT based system including balancing signal-based processing as well as communication tasks, cooperatively developing channel admittance along with routing protocols to improve network lifespan and offering self-adaptability to diverse functioning conditions by adopting appropriate learning frameworks and flexible algorithms, and protocols. Using dynamic signal processing along with channel access schemes permits a network to actively modify lifespan for signal alteration based on the demands of the application.

Taghizadeh et al (2018) [45] have focussed on packet loss as well as power diminution in an RPL-dependent network in a heavy and an extremely lively load. A Context-Aware Objective Function (CAOF) calculates the rank by considering the context of each node. CAOF evades thundering herd occurrence by slow shifting from a high to real rank value. A routing metric called Context-Aware Routing Factor (CARF) takes the residual energy and parent chain queue to the root recursively while decreasing the outcome of upstream parents as it moves down the route. Using complete assessments, the metric yields an improved decision about correct parent in the network with increased traffic dynamicity instead of determining only depending on parent rank. A parent selection scheme that chooses the finest parent depending on CARF and certain metrics while circumventing routing loops using a simple however efficient countermeasure is presented. The proposed scheme offers increased lifespan with decreased packet loss when compared to the benchmarked schemes.

Araujo et al (2018) [46] have proposed a scheme for selecting routes using FL to achieve the demands of particular applications. FL is involved in interpreting in math terms the inexact information conveyed using a collection of linguistic rules. OFs are propounded for RPL. These OFs are actively chosen depending on context-based information. The above-mentioned OFs are produced from combination of subsequent metrics: ETX, amount of hops and energy expended. The proposed system offers improved trustworthiness, network lifespan as well as QoS with reduced delay.

Kumar & Hariharan (2020) [47] have dealt with packet loss, routing overhead and load disparity in RPL dependent network. The disadvantages are dealt using propounded Dual Context-based Routing and Load Balancing in RPL based Network (DCRL-RPL). Chiefly, grid is built where the network region is divided into diverse levels of unequal grid. Ranking dependent grid selection is implemented to choose ideal Grid Head Node (GHN) in every grid. GHN schedules members based on reputation dependent scheduling. The chosen GH categorises data established from the member using Adam Deep Neural Network (ADNN) to offer improved routing. Subtle as well as non-subtle data are taken for selecting OFs. DCRL-RPL obtains improved outcomes when compared to the standard schemes in terms of energy and network lifespan. Table 5 summarises the details of Context Aware Routing Schemes in IoT

Table 5: Context-Aware Routing Schemes in IoT

Authors	Mechanism	Merits
Chen et al (2012) [41]	Context-Awareness in Sea Computing Routing Protocol (CASCR)	Offers better energy efficiency and lifespan
Kalmar et al (2015) [42]	Context-Aware Addressing and Routing mechanism (CAEsAR)	Produces lesser signalling traffic during RPL tree formation stage and system adaptation to variations of context factors
Chen et al (2018) [43]	Scalable Context-Aware Objective Function (SCAOF)	Offers better network lifespan, increased trustworthiness and efficacy
Biason et al (2017) [44]	Energy and context-based architecture	Improves lifespan

Taghizadeh et al (2018) [45]	Context-Aware Objective Function (CAOF)	Offers increased lifespan with decreased packet loss
Araujo et al (2018) [46]	Scheme for selecting routes using FL	Offers improved trustworthiness, network lifespan as well as QoS with reduced delay
Kumar & Hariharan (2020) [47]	Dual Context-based Routing and Load Balancing in RPL based Network (DCRL-RPL)	Reduces energy and improves network lifespan

Lightweight On-Demand Ad Hoc Distance Vector Routing – Next Generation (AODVng / LOADng)

The LOADng routing protocol, derived from AODV, is tailored for Low-Power and Lossy Networks (LLNs) and is designed to support devices in IEEE 802.15.4 environments. Its on-demand, reactive nature allows it to establish routes only when necessary, conserving power by minimizing control traffic. While LOADng offers advantages over RPL, particularly in point-to-point and multipoint scenarios, it faces challenges such as bugs and incomplete features.

Recent developments, such as the Load Balancing Ad hoc On-demand Multipath Distance Vector (LBAOMDV) [48] protocol, enhance reliability by optimizing energy use and network performance during peak times. Comparisons of LOADng with other protocols like RPL and its variant LOADng-CTP highlight LOADng-CTP's superior performance in smart metering applications, demonstrating higher data delivery rates and lower delays [49].

Moreover, the enhanced LOADng-IoT [50] protocol incorporates improvements for better QoS, reliability, and power efficiency in various network scenarios. The introduction of the LOADng-IoT-Mob [51] version further adapts to mobile networks, emphasizing dynamic path adjustments and more reliable routing metrics.

Overall, while LOADng and its enhancements show great promise for IoT applications, ongoing research should focus on real-world testing, addressing memory usage issues, and refining the routing mechanisms to ensure robustness and efficiency in diverse environments.

Table 6 : LOADng based Routing Schemes in IoT

Author	Mechanism	Merits
Alghamdi, Saleh A. (2015) [48]	Dynamic load balancing	End to End Delay, reducing the energy consumption and frequency of node breakdowns
Tahar Ezzedine et. al, (2015) [49]	Collection Tree Protocol Mechanism	Higher Packet delivery ratios, lower delays, and lower overhead
Sobral, José VV et.al. (2019) [50]	The Internet route discovery process, the Internet Route Cache (IRC) system, and a new error code for RERR messages	PDR, reduce the energy, reduce control message overhead
Sobral, José VV, et. al. (2019)[51]	Expanding Ring flooding Mechanism (route discovery), Control Messages Harnessing (Routes Management) weak RSSI routing metric Cooja Simulator	Improve the PDR, lower latency, Increase the speed, and reduce the overhead.

CONCLUSION

The rapid expansion of the Internet of Things (IoT) brings forth significant challenges, particularly in relation to limited device resources and low-power networks. Efficient routing solutions are essential to address these challenges, and energy-aware protocols, such as RPL and bio-inspired algorithms, have made notable advancements in improving energy efficiency, network lifespan, and overall performance. Additionally, techniques

like load balancing, energy harvesting, and machine learning have further strengthened these protocols, helping to mitigate issues such as congestion and uneven load distribution. As bio-inspired and RPL-based routing methods continue to evolve, they hold the potential to play a crucial role in shaping the future of IoT networks. Ongoing research and real-world deployment will be vital to enhancing scalability, energy efficiency, and adaptability, ensuring that IoT networks can effectively meet the growing demands of diverse industries.

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