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Routing Protocols in Internet of Things: A Survey

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Abstract:
Internet of Things is a buzz word now a day. It provides highly dynamic network with resource constraint devices. In such dynamic environment, it becomes very difficult to maintain the topology of the network and creates several hurdles in the routing process due to nodes mobility and resource constraint nature. It has been recognized that majority of energy of the nodes in IoT network is used in setting up the topology and retaining the topology with the help of control packets. The aim of this work is to study currently existing routing protocols in the IoT domain and wireless sensor networks and find out the various challenges in the current routing process of IoT networks.

Keywords: *Internet of Things (IoT), Wireless Sensor Networks (WSN), Routing.*

I. INTRODUCTION

Due to the technological revolution, the concept of traditional network has changed. The current networks are becoming more and more versatile with the inclusion of different types of mobile sensor devices, internet objects and other electronic devices [25][26]. The IoT network contains huge number of things which are inexpensive as well as smart in nature. The smart things can be residing in anything right from industry machinery to any household equipment. The inclusion of smart things into such devices makes these devices smart and it results into making the overall environment intelligent for increasing the comfort in human life. Normally, smart sensor nodes contain a processing unit with less computational power and limited resources such as memory and battery supply. This poses a need of using these resources with due care.

One of the most important reason of worry is still there is not any universally accepted protocol stack for the IoT network. It makes the network more heterogeneous and brittle in nature. The communication between the heterogeneous devices becomes herculean task. Along with it, many of the researchers have discussed about the issues such as node deployments, diverse networking standards, Multihop communication due to short range of the devices, intermittent connectivity, mobility of the devices and many more. These challenges invited many researchers and academicians to study in this area. The main objective of this paper is to discuss various currently existing protocols in this domain and find out the research gaps that can be fulfilled by further study.

This paper is organized as follows: section II of this paper discusses about various routing protocols which are currently existing, section III talks about routing challenges that are need to be addressed for the betterment of IoT networks in the future and last section concludes the survey with some inferences.

II. ROUTING PROTOCOLS

An intelligent routing recovery technique known as Multi-Particle Swarm Immune Cooperative Algorithm (MPSICA) is proposed in [1]. This technique is designed for heterogeneous Wireless sensor network. This algorithm overcomes the problem of discontinuities in the path and also tackle the problem of energy depletion in nodes. For extending the network lifetime, it focusses on creating a powerful transmission background for

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data delivery. Authors done experimentation and shown that lifetime of the network can be extended by tumbling the failure in data delivery.

A cluster-based routing protocol is proposed in [2] uses a fuzzy C means algorithm. This fuzzy algorithm prominently used for energy consumption balancing at cluster level which further improves the network lifetime. Authors have initially the setup the network for transmitting the data. While setting up the network formation of clusters is done and from every cluster a cluster head is elected by considering the highest residual energy of the nodes inside the cluster. Authors addressed the energy conservation in the network by using data fusion and data transmission schedule. Authors reduced the amount of the data using data fusion technique and they used the transmission schedule for switching on and off the radio transceiver. The performance of this algorithm is compared with modified LEACH algorithm. Simulation shown that the lifespan of the network improved by 2 to 4 hours for various sets of nodes.

Rajeev Kumar *et al.* [3] presented multi objective fractional artificial bee colony algorithm. This is an efficient energy clustering method. It is a blending of fractional calculus with artificial bee colony algorithm. Using better mathematical formulations, authors proposed a new objective function for enhancing the energy level for sustaining it over a longer lifespan. In this work, authors succeeded to minimize the intra cluster distances. They come up with a fitness function based on energy, delay and distance. In the experimental analysis, the proposed work is compared with Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC) and Low-Energy Adaptive Clustering Hierarchy based routing algorithms to show that the proposed algorithm outperforms the existing ones.

A routing protocol is developed in [4] by the authors by using the artificial bee colony algorithm for cluster based wireless networks. The objective behind this work was to improve the lifespan of the wireless sensor networks. For maintaining the Quality of the Service, the signal delays are taken into consideration. Further the performance of this algorithm is compared with the existing algorithms such as particle swarm optimization and low energy adaptive clustering hierarchy approach. As per the simulation results, authors stated that by reducing the delays in the network can increase the overall lifespan of the network. In this approach authors used static nodes while doing the experimentation. As a future enhancement, they suggested to do routing using mobile nodes using artificial bee colony approach.

In [5] CarynthiaKharkongor*et al.* proposed an energy evaluation model and the efficient energy routing protocol in the Internet of Things network. The main feature of IoT network is these types of networks are heterogeneous in nature and it is considered to be a revolution in the traditional internet. Along with the regular data transfer mechanisms between the nodes, the nodes need to do regular communication for resolving the various run time issues in the network. IoT networks gets alter regularly due to mobility of the nodes. Many times, these networks contains the resource constrained nodes having limited battery power as well as less computational capabilities. So, it becomes necessary to use these resources carefully for improving the lifespan of the networks. In this work, authors came up with a centralized controller that plays vital role in the routing process by monitoring the network topology, managing the scalability of the network as well as by improving the network lifespan. From the experimental analysis it has been shown that with this algorithm, the throughput of the network is increased and average end to end delay is reduced in comparison with the existing protocols such as Destination Sequenced Distance Vector (DSDV), On-Demand Distance Vector and Dynamic Source Routing protocols.

An energy efficient cluster-based routing protocol [6] for is proposed by Jau-Yang Chang *et al.* in the IoT environment. Authors focused on structuring of the clusters and tried to reduce the dispatching

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distances between the sensor nodes. Reducing the dispatching distances resulted into dropping the expenditure of the energy and improving the network life span. Center of gravity is calculated using the cluster's every member node's residual energy and cluster head is selected based on it. With experimentation, authors stated that the performance of this proposed algorithm is better than the existing protocols and further they endorsed this protocol for employing in the large scale IoT networks.

In [7], fuzzy logic-based Clustering method in Wireless Sensor Networks is proposed by the authors by using the energy prediction. In this work, authors handled the uncertainties by using the fuzzy interference system (FIS). On the basis of residual energy and expected residual energy the selection of cluster head is done. Using 18 fuzzy mapping rules the probability of selection of a node as cluster head is calculated by the authors. De-fuzzification of the calculated probability is done on the basis of Center of Area (CoA) technique. The nodes with high residual energy and anticipated remaining energy were given higher preferences in the race of becoming the head of the cluster. On the basis of the experimentation results, authors proved that fuzzy logic-based method is performing more proficiently compared to other methods. The limitation in this approach was, it was designed only for static nodes.

Xiao Chen *et al.* [8] proposed a probabilistic routing protocol. This protocol works in the heterogeneous Wireless Sensor Networks and provides definite delivery rate. As per the need of applications various types of sensor nodes are used in the network. These nodes are heterogeneous in nature and which need to do the communication. In such type environment it becomes difficult to design and develop the scalable and reliable protocol. Due to asymmetric links present in the network communication becomes difficult but the special thing about this protocol is, it exploits these links for dropping the extra overhead on the network and attaining the guaranteed delivery rate. Preparation and routing are the two important phases of this protocol. In preparation phase, reverse paths for asymmetric links are found out. Neighbor relations are used for finding it. In the routing phase, node selection, message forwarding along with the acknowledgement sending is done. For attaining the guaranteed transmission rate probabilistic approach is used. For minimizing the network traffic, the data is transmitted with specific probability. For achieving less energy utilization, as per the traffic in the neighboring nodes, the data transmitting probability is decided. From experimentation results authors evaluated the performance of the protocol.

For the heterogeneous Wireless Sensor Networks, D. L. Guidoni*et al.* [9] proposed a routing protocol. For the deployed physical topology in the heterogeneous network, many logical topologies are built by the authors. In this work, two types of sensor nodes: L-sensors and H-sensors are used by the authors based on their capacities. They used the term L-sensors for indicating the sensor nodes having low hardware capacity, while the H-sensors term is used to represent the sensor nodes having better hardware configuration. During the data communication each application specific topology maintains a tradeoff between latency and energy consumption. From the experimental results, it is stated that the proposed routing protocol offers different topologies depending on the type of the application.

For efficient execution of applications in Wireless sensor networks, it is necessary to conserve the sensors energy and balance the traffic load [10]. In this paper authors stated that, if the energy is conserved and traffic load is balanced so that there will be very less chances of creation of energy holes and the network topology will be in connected state for longer time. This will help to extend the lifetime of the network. By considering these facts, authors developed a protocol Cluster Chain Weight Metrics approach (CCWM). Using this protocol, authors does selection of the cluster heads efficiently to achieve the goal of extending lifetime of the network. Authors have used Weight metric for selecting cluster heads. Cluster structuring takes place after selecting cluster heads. Computation and

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communication cost are minimized by using the local clustering mechanism. The proposed algorithm shortlist group of nodes having the position metric. The position metric is calculated using average energy of nodes, node's degree and sum of distance with all its neighbours. The node having highest position metric value is selected as cluster head. Through simulation, authors compared the outcome of this algorithm with the existing algorithms and stated that it performs better than the existing models with respect to energy consumption.

Deployment scheme for Green Internet of things environment is proposed in [11]. Authors have collectively organized several objects in the network in the cost-efficient manner. Several assistancewere made in this approach on the basis of hierarchical system approach. For controlling the energy usage, optimization model was constructed. Authors designed Steiner Tree algorithm for reducing the usage of energy and to assist the optimization model. After experimental analysis it has been shown that with the help of the proposed deployment scheme, the lifetime of the network was extended as compared to the traditional deployments of sensor nodes. In the future scope, authors suggested to think about the compression techniques for data fusion for attaining Green Internet of things.

For extending the network lifetime, Ant Colony Optimization (ACO) technique [12] is proposed by Ying Lin *et al.* In this approach authors addressed the issue of network connectivity and sensing coverage by discovering extreme number of disjoint connected covers in the network. This algorithm considered the devices as the vertex of the graph. On the basis of heuristic and pheromone data, the maximum number of stationary paths are calculated. Best solutions are attained with the help of local search scheme for evaluation of efficiency and effectiveness of the network. Thus, the lifespan of the heterogeneous network can be extended by reducing the computational time. From the experimental analysis, the performance of the heterogeneous network can be evaluated based on the redundancy and then it was compared with the greedy algorithm.

Energy-aware selection of cluster heads using particle swarm optimization (PSO) algorithm for the wireless sensor network is discussed in [13]. The major hurdle in wireless sensor networks is resource scarcity. These networks are having limitation in terms of energy. The lifetime of the network is extended using the clustering-based approach by the authors in this work. Using PSO algorithm, authors reduced the cost for detecting the head node and also achieved the higher convergence rate. Parameters like node degree, left over energy, intra cluster distance and the headcount for each cluster heads are used in the objective function evaluation. This approach also considers the side effects occurred due to packet drops and packet retransmissions with respect to the energy consumption. The performance of this approach can be evaluated by comparing with several other protocols such as clustering based particle swarm optimization and clustering based low energy adaptive clustering hierarchy approach. From experimentation, authors stated that particle swarm optimization approach has got better results with respect to energy utilization, its lifespan and the number of packets transmitted to the base station. Authors suggested to use the distributed particle swarm optimization for the heterogeneous WSNs while doing the future work.

OanaIova*et al.* [14] proposed a multiparent RPL protocol for improving the lifetime of the network. In this algorithm, authors proposed the Expected Lifetime metric having the remaining time of an individual node till it runs out of energy. In this work, authors developed a mechanism for detecting nodes having energy-bottlenecks and distributing the data traffic load uniformly among the nodes. In this work authors constructed a Directed Acyclic Graph based on the Expected Lifetime metric, which precisely guesses the lifetime of all the paths in the direction of the border router. By choosing the parent nodes having the strongest paths authors extended the lifetime of network.

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Kazuhiko Kinoshita *et al.* [15] proposed an algorithm for fair routing. In this algorithm authors introduced an energy pool as a broker for maintaining the overall energy consumption amount by using a technique of cooperative forwarding. Authors improved the lifetime of the networks using cooperation in multiple networks. After discovering routes, in this case a sensor node selects a route that has the minimum cost in terms of the total number of traversing nodes with an advantage that using shared nodes having adequately large power supply or batteries for reducing the energy utilization of other nodes.

Collaborative routing-based approach is proposed by BashyalS. *et al*. in [16]. In this work, authors stated the CRAWL approach which is adaptive to the distribution of available energy in the sensor network which is uneven in nature. When the existing energy distribution is even, the performance of collaborative and non-collaborative algorithms is almost same, but when existing energy distribution is uneven, collaborative algorithms outperform the other and provides 20% more network lifespan. For attaining this, the authors proposed different node scheduling options.

Authors in [17] proposed a handoff algorithm for energy conservation of wireless sensor network. One of the significant features of such networks is the due mobile stations the variation in signal is caused and due to that the problem of intermittent connectivity takes place. Intermittent connectivity either breaks the existing radio transmission link between a sink node and that of the mobile node or it may degrade the signal quality. So, in such situation, authors stated the importance of switching or handoff, which establishes the link of the mobile device with other base station. This ensures that the signal quality is maintained by reducing the interference with other radio links and resulting into energy conservation that occurs due to retransmission of data or packet drops.

A resource reservation system is designed by the authors in [18] for efficient handling of the energy in wireless sensor networks. This system contains hands off mechanism for small size cells which makes use of transfer probabilities for guessing the destination cell. In this case, the resources reserved in each sink station are proportionate to the transfer probabilities of user. In order to get precise value of transfer probabilities, they build a movement or motion model to study the association between the user's initial states and its transfer probabilities. As per the authors, this algorithm turned out to be very easy to build and adjustable in diverse circumstances. It could offer correct organization about the user's haphazard movement in small size cells and improves the efficacy when resources are inadequate in wireless systems [18].

For improving the energy efficiency without losing the network performance, authors in [19] designed an algorithm on the basis of opportunistic communication topology control. This method forms a connected infrastructure by intelligently selecting a group of nodes and permits the other nodes to connect this infrastructure directly. The nodes residing in the infrastructure are termed as coordinator nodes. The nodes other than the coordinator nodes are kept in sleep mode until there is a need to connect the infrastructure. This minimizes the requirement of energy and the energy is saved to great extent. Authors developed a control algorithm for controlling the topology and lessening the count of coordinator nodes by retaining the network performance and conservation of energy.

Most of the times, sensor nodes in the deployed network are having battery power constraints. Many of the researchers across the world are taking it as challenge for extending the networks lifetime. Load balancing process goes hand in hand with the network lifetime. In this algorithm [20] authors focused on balancing the traffic load in the network for avoiding the issue of energy hole creation. In the data routing process, this algorithm used event-based reactive approach. Request and reply message are

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used for the communication in this routing technique. The implementation shows enhancement in throughput for multimedia information and extended lifetime of the network. The route setup is done by considering remaining energy of the nodes.

In [21] authors proposed An Efficient Cluster-based Power Saving scheme for Wireless Sensor Networks. This protocol selects the cluster head by using average residual energy of sensor network, remaining energy of individual sensor nodes and the sensor node's location. If the energy of the sensor node is more than that of the average energy of the sensor network, it became eligible for being a cluster head. Authors used load balancing mechanism for improving the network lifetime. The limitation of this algorithm was due to its centralized approach and requirement of exact location information of individual node.

Energy-efficient geographic routing (EEGR) protocol is discussed in [22]. This is a stateless and fully localized protocol. In this protocol, authors consider energy utilization and location of the node for taking the routing decisions. The packets are sent to energy optimal relay position in spite of forwarding them to the neighboring node having maximum remaining energy or to the neighboring node which is nearest to the sink station. The protocol is designed in such a way that, it is not necessary to keep the information of all the neighboring nodes to every node. Small control packets are broadcasted containing the information of location and residual energy for computing the optimal relay node.

Jin *et al.* [23] proposed A Practical Passive Cluster based Multipath Protocol (PPCMP). In this algorithm, after detection of an event, the node closer to the event performs as candidate cluster head and goes into wait state for small time span. It waits for the cluster head advertisement in that time span. If it does not receive any such advertisement in that time span, it starts acting as a cluster head. The node within its range becomes cluster members and the nodes outside its range follow the similar process for the formation of cluster.

Wang *et al.* [24] proposed a routing algorithm for mobile nodes in cluster-based environment. In this protocol every sensor node gets the information about its neighbors in terms of their location and residual energy by broadcasting a control packet in its vicinity. The nodes having maximum residual energy are selected as cluster heads. Every cluster head sends advertisement packet in its range and urges the nodes in its vicinity to join the cluster. Using random waypoint mobility model, the sink node moves in the network and every time it sends the information about its new location to the network nodes. Routing path is created towards the sink node by the cluster head based on the information received from the sink node about its location.

III. CHALLENGES

Data routing is going to play a crucial role in the IoT environment. Many researchers are working in this area. The things connecting to the internet are rapidly increasing day by day and the manufacturers producing the things are also increasing day wise. This is making the routing problem severe due to non-existence of standard protocol stack. Section II clearly state that, there is a need of routing protocol for reliable routing of the data. The prominent reasons are heterogeneity of devices, intermittent connectivity due to frequent changes in the network topologies, death of existing nodes, malfunctioning of the nodes, mobility of nodes, resource constraint nature of the nodes in terms of battery power, processing power and memory etc.

IV. CONCLUSION

Due to the technological advances, internet has changed a lot and still the changes are going on. This has opened huge numbers of doors in front of the researchers. Few years back, researchers were thinking that, they will use the protocol stack of traditional networks as it is in the next generations networks, but very soon the limitations of traditional protocol stack with respect to future networks reveled and researches understand the need of

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development of new protocol stack for IoT networks.

The count of devices is getting increasing day by day and surveys says that the total devices will be 40 times more than that of the people who will use internet till 2020. If these devices want to communicate with each other, definitely there is a need of standard communication protocols. The major intention behind the IoT technology is to increase the comfort of human life, so it is necessary that the devices must communicate with one another in seamless manner and need to transmit the data from one location to other. This has underlined the importance of routing in next generation networks, but as the devices are constrained in terms of resources such as battery life, memory and processing, it become necessary to optimize their use for improving their overall performance on the network.

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