A Survey on Enhancing Wire/Wireless Routing Protocol Using Machine Learning Algorithms

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Abstract. Routing is a technique used for choosing the best network’s path and forwarding the data over the selected path. This paper investigates the enhanced routing algorithms for wire/wireless networks through making a deep study of the most new routing algorithms in those networks, then analyzing these algorithms to examine the efficiency and effectiveness of the analyzed algorithms. Moreover, the paper deals with OSPF for the wired network and AODV for the wireless network. The emphasis of this research paper is concentrated on the survey in routing algorithms that used in wired and wireless networks such as OSPF and AODV because such algorithms are the best suitable kinds for the two types of Networks. The next subsection describes the basic features of these protocols. This paper also focuses on the common points in wire/wireless routing algorithms and using machine learning techniques for enhancements and improvements.

1. Introduction
The communication networks goal is to allow us to access the needed information anywhere and everywhere [1]. Computer networks are mainly classified according to their characteristics into wired and wireless networks. The wired networks use cables for connection such as coaxial cable, Ethernet, optical fiber and twisted pair [2]. Such networks have many advantages and disadvantages. The main advantages of them are: Offering the fastest transfer speed of all the networks, not prone to interference and fluctuations, having a better security system than wireless networks. While the wired networks disadvantages are the lacks of mobility and their large cost. The wireless networking is a technique that used in telecommunications networks, homes and in business installations for bypassing the highly cost process of using cables for connection between different devices in different locations [3]. The telecommunications in Wireless networks are generally carried out by using a radio communication. Wireless networks have various types such as: Wireless PAN, Wireless LAN, Wireless MAN, Wireless WAN, Cellular network, Wireless ad hoc network, Global area network, Space network. A wireless ad hoc network (WANET) or Mobile ad hoc network (MANET) is one kind of decentralized connectionless network. The network is called ad hoc because there is no prior infrastructure that the network depends on, for example the wired networks use routers or wireless networks use access points for connection. Instead, each node forwards data for other nodes to participate in routing, so the routing algorithm and network connectivity are used for dynamically determining of which nodes that forward data [4]. A wireless network has many advantages and disadvantages. The Advantages are: Cheaper than wired Networks in term of cost, maintenance,
installation, Mobile and versatile, they can easily be set up and disassembled and can provide quick and easy access to the internet and workspaces. Whereas their disadvantages can be given as: Unreliable and not secure, they have limited bandwidth and have an increasing chance of jamming and interference, When too many people use wireless networks, the band of air which being used to transmit signals can become overloaded.

2. Routing Protocols

The first paragraph after a heading is not indented (Bodytext style) Routing is the process used for paths selecting in the network that needed for packets forwarding from source to destination [1][4]. The routing protocols are divided into two types: one for wired networks and another for wireless networks [1].

In the wired networks, the routing protocols are classified either according to the purpose of their use into: External routing protocols and internal routing protocols, Or classified depending on the mode of operation into: Link state, Distance vector, Path vector, Hybrid routing protocol.

Distance vector routing protocol depends on the calculation of the pathway weight cumulatively, often using the Bellman-Ford algorithm or one of the similar algorithms. The routing protocols working with the link state algorithm depends on the construction of a complete topology for the network before calculating the weights of the paths. And some protocols may have mixed behavior from the two previous groups, which is called hybrid routing protocols. The path vector protocols are based on the path vector algorithm, which is similar in principle to the Bellman-Ford algorithm, but it is capable of solving the loop problem on its own, and it maintains information about the path itself instead of cumulative weight only. The routing protocols are also classified by protocol behavior with IPv4 address space, either a Classful or Classless Routing Protocol. The standard routing protocol is a routing protocol that deals only with standard networks from (A), (B) or (C). The non-standard routing protocol is capable of understanding and routing packets to non-standard networks, i.e. networks resulting from network fragmentation. [36]. they also are classified by the layer in which the protocol operates in the standard communication model (OSI), routing protocols may operate in the second, third or seventh layer, see table 1.

Table 1. Taxonomy of Wired Routing Protocol

| Routing protocol | Classification according to the purpose of use | classification according to the operation mode | Classification according to internet protocol | Classification according to OSI layer |
|------------------|-----------------------------------------------|-----------------------------------------------|----------------------------------------------|--------------------------------------|
| Routing information protocol (RIPv1) | internal | Distance vector | IPv4, standard | Application layer |
| Routing information protocol (RIPv2) | internal | Distance vector | IPv4, non-standard | Application layer |
| Routing information protocol (RIPng) | internal | Distance vector | IPv6 | Application layer |
| Open shortest path first (OSPFv2) | internal | Link state | IPv4, non-standard | NW layer |
| Open shortest path first (OSPFv3) | internal | Link state | IPv6 | NW layer |
| Intermediate system to intermediate system (IS-IS) | internal | Link state | IPv4, non-standard | Data link layer |
| Enhanced Interior gateway Routing protocol (IGRP) (EIGRP) | internal | Distance vector | IPv4, standard | NW layer |
| Border gateway (BGP- | External | Path vector | IPv4, non-standard | Application layer |
Wireless Networks Routing protocols can be classified into [5]: Table driven and on demand. The first creates the routing tables in advance and keeps them up-to-date permanently; the second only calculates the route when needed. Later, this classification has been expanded to include three groups: The active, Proactive and Hybrid protocols. The proactive routing protocol creates the routing table proactively, while the active routing one work on demand or when is needed, while the hybrid routing protocol has the two behaviors. The wireless routing protocol can be classified according to network topology into: (1) Flat topology, which deals with the entire network topology at once. (2) Hierarchically topology, which deals with the network hierarchically. Routing protocols in mobile networks are often compared to the topology structure, path availability, periodic updates, storage need, delay and scalability, see table 2.

Table 2. taxonomy of wireless routing protocol

| Protocol name                  | Classification according to algorithm work | Classification according to network topology |
|-------------------------------|-------------------------------------------|---------------------------------------------|
| Wireless Routing Protocol     | proactive                                  | Flat                                        |
| (WRP) Protocol                | proactive                                  | Flat                                        |
| (GSR) Protocol                | proactive                                  | Flat                                        |
| (FSR) Protocol                | proactive                                  | Flat                                        |
| (STAR) Protocol               | proactive                                  | Hierarchical                                |
| (DREAM) protocol              | proactive                                  | Flat                                        |
| (MMWN) Routing Protocol       | proactive                                  | Hierarchical                                |
| (CGSR) Protocol               | proactive                                  | Hierarchical                                |
| (HSR) Protocol                | proactive                                  | Flat                                        |
| (OLSR) Protocol               | proactive                                  | Flat                                        |
| (TBRPF) Protocol              | proactive                                  | Flat                                        |
| (AODV) Routing Protocol       | Active                                     | Flat                                        |
| (DSR) Protocol                | Active                                     | Flat                                        |
| (LMR) Protocol                | Active                                     | Flat                                        |
| (ROAM) Protocol               | Active                                     | Flat                                        |
| (TORA) Protocol               | Active                                     | Flat                                        |
| (ABR) Protocol                | Active                                     | Flat                                        |
| (SSA) Routing Protocol        | Active                                     | Flat                                        |
| (RDMAR) Protocol              | Active                                     | Flat                                        |
| (LAR) Routing Protocol        | Active                                     | Flat                                        |
| (ARA) Protocol                | Active                                     | Flat                                        |
| Flow Oriented Routing Protocol| Active                                     | Flat                                        |
| Cluster-based Routing Protocol| Active                                     | Hierarchical                                |
| Zone Routing Protocol ZRP     | Hybrid                                     | Hierarchical                                |
| (ZRLS) Routing Protocol       | Active                                     | Hierarchical                                |
| (SLURP) Routing Protocol      | Active                                     | Hierarchical                                |
| (DST) Routing Protocol        | Active                                     | Hierarchical                                |
| (DDR) Protocol                | Active                                     | Hierarchical                                |

2.1. Problems of Routing
A routing protocol must ensure traveling of data between end points through the network (or among groups of nodes for multicasting) [30]. The producing network should be capable of supporting the following: (1) the networks should be loaded in heavy and light manners, (2) The situations of overload, (3) Traffic patterns fluctuation, (4) Avoiding routing oscillations and loops, (5) Response
rapidly to any demand of resources, (6) Guarantee of Quality of Service (QoS), (7) The ability to plan for booked traffic, (7) Work in a multi-supplier condition where some system state data may not be accessible outside supplier areas, (8) End-to-End and/or multicast traffic.

3. OSPF
OSPF stands for Open Shortest Path First which is a routing algorithm for Internet using. It utilizes a link state in the individual regions that being used for making up the hierarchy. It depends on Dijkstra's algorithm for computing the shortest path tree into each areas of the network.

3.1. Dijkstra's Algorithm
Dijkstra's is an algorithm that has been used for finding the shortest-paths between nodes in the graph from a source node to a destination node and the algorithm stops once the shortest route to the destination node has been found. [6]. The main advantages of the algorithm is its usage to determine Open shortest Path First [6]. The disadvantages of the algorithm are: Its blind search so it wastes a lot of time through processing, It cannot handle negative edges, It leads to acyclic graphs (loop) and most often cannot find the right shortest path [6].

4. Ad hoc On-Demand Distance Vector Routing (AODV)
AODV is an algorithm for routing which is used for mobile ad hoc networks (MANETs) and other wireless ad hoc networks. It is an on-demand routing protocol for ad hoc networks, it uses hop-by-hop routing by maintaining routing table entries at intermediate nodes. The algorithm has three phases, namely: Route Discovery, Route Table Management, Path Maintenance and Local Connectivity Management [7].

The AODV advantages are: (1) Fast response to the topological changes that affect the active route, (2) it supports both unicast and multicast, (3) Minimum setup delay, (4) No additional delay can be put on data packet, (5) It needs no central administrative system to handle routing process, (6) It is loop free, self-starting, and can be scaled to large number of mobile nodes.

Its disadvantages are: (1) the need for large number of control packet to be generated when a link breakage occurs, these increase the congestion, (2) Processing demand is very high, (3) A large share of bandwidth is consumed, (4) Routing table takes a long time for building, (5) The useful route may have expired and it is difficult to determine reasonable expiry time, (6) The network size can be increased whereas different performance metrics can be decreased.

5. Artificial Intelligent and Machine Learning
Artificial intelligence techniques provide an efficient tool for optimizing multiple conflict goals and for estimating in exact parameters of the network, simultaneously [8]. While the purposes of machine learning (ML) is to learn the environment properties automatically and to modify their behavior fast and with ease according to them. Routing algorithms have considered different properties such as: limitations of memory, costs of the communication, energy restriction. Furthermore, many ML strategies are found but their suitability for the networking domain is unclear [8]. AI & ML utilize the data of the past traffic for learning the best routing configurations for the future conditions [8][9]. Intelligent algorithms, ACO, RL, GA, FL and NNs, respectively are being used for routing protocols.

5.1. Reinforcement learning
(RL) is a machine learning technique that attempts to generate patterns or rules by using computer programs. RL is used to maximize the performance of the network by finding the optimal result from the environment [30][33], as shown in figure 1.
5.2. The Ant Colony Optimization (ACO)
ACO is an algorithm that was established from the actual ants’ behavior. The ACO uses pheromone as a mediator for the communication among each other. The pheromone is an unsteady chemical substance that emitted by ants, in which their decisions of moving are affected by it. The ACO-based routing protocols use the probability distribution to select routing path, this will make a good connectivity from nodes to the base-station. Therefore, the network life time is optimized by such protocols [9][32][34].

5.3. Practical Swarm Optimization (PSO)
Particle swarm optimization (PSO) algorithm is based on the nature of the swarm intelligence, it is generated from the nature behavior of a flock of birds, i.e., how they can move in the search space for exploring and exploiting the food and shelter [31][35]. Figure 2 shows the movement of particles in search space. PSO consists of number of particles that were named swarm, each particle gives a solution. PSO evaluates each particle to verify the quality of the solution by using a fitness function. The goal of PSO is to find the position of the particle which gives the best evaluation of the given fitness function. PSO is used to minimize energy consumption and increases network lifetime [31][36][37].

5.4. Fuzzy Logic (FL)
FL is a mathematical system that was founded for expressing a human reasoning approximation. In FL, intermediate values can be established based on inference rules and linguistic variables, in fuzzy
set, each element has a partial membership between 0 and 1 ranges. Linguistic variable values are words or sentences, and inference rules that are used for governing the reasoning approximation. Inference rule can be formulated by the linguistic variable. The protocols based on FL are used for perfuming the clustering or for optimizing the route to obtain multiple objectives. It uses fuzzy rules and membership functions for designing the cost functions to optimize multiple objectives. FL is employed to increase the network lifetime. Also, non-optimal solution can be generated by FL, and the topology changes can be re-learnt via using the fuzzy rules [9], as shown in figure 3.

5.5. Genetic Algorithm (GA)
Genetic Algorithm (GA) is based on the natural evolution which selects the best population by performing fitness tests on new structures, as shown in figure 4. A group of chromosomes is called a population being used for performing complete solutions to a specified problem. GA uses fitness value to show a chromosome quality according to the problem needs [9]. Those chromosomes are generated randomly, then each chromosome is evaluated by using fitness function. When a chromosome has the highest fitness value, it will have a higher chance to be selected for crossover to create new chromosomes. Crossover is a method for recombining two chromosomes, and this will lead only the offspring chromosomes that will inherit the parent chromosomes’ traits, for this reason a problem in the next generation will appear, such problem includes no new genetic chromosomes are introduced. Therefore, GA uses a mutation for introducing a new genetic patterns [9]. The GA algorithm is capable of discovering the search space efficiently through crossover which is used to evaluate the fitness in parallel and to mix the partial solutions [9]. Genetic Algorithm can be used clusters building in wireless network sensor. Routing based on GA will create a tree that collects all sensor nodes, and it will extend the lifetime of the network [9].
5.6. A Neural Network (NN)

A Neural Network (NN) is a network that consists of neurons, the neurons are organized as input, hidden and output layers. The architecture of NN is shown in figure 5. There are different models of NN which differ in connections layers. NNs define their inter-relationships, learn the patterns and updating the weights of the NN's to find the input data patterns. After the completion of the learning phase successfully, the NN model needs to prove the performance by using the testing set independently [9]. The performance of the routing algorithm can be improved by NNs. NN takes into consideration the latency, rate of error, duty cycle and throughput for link quality determination [8] [9].

![Figure 5 A simple ANN architecture with different layers](image)

| Intelligent method used in routing | Enhancements |
|-----------------------------------|--------------|
| RL                                | decreases energy consumption, has much better connectivity, Reduces latency, improves link reliability, Increases packet delivery |
| ACO                               | provides better energy efficiency, decreases energy consumption, reduces latency, increases packet delivery, Builds multiple, has much better connectivity |
| FL                                | Used for postponing the first node’s dead time |
| GA                                | Provides better energy efficiency, postpones the first node’s dead time |
| NN                                | provides better energy efficiency, reduces latency, increases packet delivery |

6. Related Work

Below are some of the related works that explain the modifications for routing in wired / wireless networks and show the intelligent techniques that have been used for modifications. The previous related works for wired networks can be given as follows:

- Yong Deng et al. they developed the Dijkstra algorithm with fuzzy arc lengths to solve the problem of shortest-path. In their paper, two problems were solved, the first is to find a method for determining the two edges addition. The second is to represent the length of edges by using fuzzy numbers then find a method for comparing the distance between the different
paths. The proposed method represents the fuzzy numbers by using the graded mean integration for finding the shortest path by using fuzzy arc lengths [10].

- Dr. Manar & Zena Natiq made a proposal to solve the congestion problem in an OSPF based best effort network. The congestion problem was predicted in the computer network links by using a simple feed-forward neural network. The training of the neural network is based on a given traffic pattern to predict congested links. These predictions are used to modify Dijkstra's algorithm for the shortest paths selection, which excluding those links [26].
- Mingjun Wei & Yu Meng proposed a suggestion to improve Dijkstra-algorithm by using weight function depending on analyzing Dijkstra-algorithm. The results show that the improved algorithm can overcome the shortcomings which appear in the traditional Dijkstra [11].
- Khyrina Airin et al. in their paper they found new method to modify the Dijkstra’s algorithm for finding the safest and shortest path. The first modification is to restrict the node's direction of floor plan; and the second modification is to block the nodes that affected by fire [27].
- Guo Qing et al. enhanced Dijkstra algorithm for finding several shortest paths that exit in the rectangular map, then introduced the identification of turn node for finding shortest travel time paths’, this method was used for the problem of path planning with many shortest paths, and for finding the optimal paths with both the shortest distance and travel time in the Automated Storage and Retrieval System (AS/RS) for Automated Guided Vehicle (AGV) [12].
- Yang Zhang et al introduced a new method for traffic incidents based on density clustering specifically called DBSCAN, which joined an enhanced Dijkstra algorithm with DBSCAN (density based spatial clustering of applications with noise) [28].
- Md. Nazmul et al suggested Dijkstra shortest path first (SPF) algorithms used for the specific shortest link searching among all links, then a database table was built to the router state. If the size of state table is small amount, then OS of the router will use a little amount of clock cycle [29].

### Table 4 Comparison of various ML techniques with Wired NW

| References | Method | Enhancement |
|------------|--------|-------------|
| [10]       | Fuzzy  | Locates the shortest-path and finds a solution to the uncertainty problem in the shortest-path that caused by the weather and other unforeseen factors, and uses a fuzzy variable for travel-time representation that starting from first city to the next city. |
| [26]       | NN     | Solves the congestion problem |
| [11]       | Modification of node direction and blocked the effected nodes | Solves the Dijkstra problem for finding the optimal path |
| [27]       | The Dijkstra algorithm was improved through holding all similar distance nodes from the source node as the intermediate nodes, then the search will begin from all the intermediate nodes until arriving to the objective node | Finds the safest and shortest path |
| [12]       | The Dijkstra algorithm was improved through holding all similar distance nodes from the source node as the intermediate nodes, then the search will begin from all the intermediate nodes until arriving to the objective node | solves the problem of route planning with many shortest-paths, and the optimal-paths is founded with the travel time and shortest-distance |
| [28]       | Clustering | Reduces the computation cost, increase the route flexibility and it can able to use in parallel and it is distributed computing resources utilization. |
| [29]       | Modified SPF | Reduces the size of routing table and save the state-database size of a router, this will result better convergence time |
The previous related works for wireless network can be given as follows:

- Dhanalakshmi Natarajan & Alii P Rajendran made a suggestion to use Dijkstra's algorithm enhancement to develop OLSR protocol called advance OLSR (AOLSR). This enhancement enabled the multi path routing. For routing, it utilized the energy and the mobility of the nodes. This paper introduced two functions, the first one is applied for node disjoint or link disjoint paths. The second function is applied to recover the paths and discover the loop that used for the network topology management [15].

- Hamideh Fatemidokht & Marjan Kuchaki Rafsanjani proposed a new routing protocol for VANET based on fuzzy logic called F-Ant. This protocol used bandwidth for computing validity of link, Congestion Metric (CM) and Received Signal Strength Metric (RSSM). The suggested protocol guarantees the safety of the road and expect to satisfy some requirements of Quality of Service (QoS) for example high data delivery ratio of the packet in the minimum point-to-point delay. In many cases, this protocol is unprotected against various security dangers [16].

- Ajay Kumar Yadav et al. proposed a (EFMMRP) Multi constraints Multicast Routing Protocol based on Fuzzy logic, which used a minimum value of fuzzy cost for multi-cast routes selection to restore the performance of network [17].

- Hua Yang, Zhimei Li & Zhiyong Liu suggested a new method for route optimization by using a continuous Hopfield Neural Networks (HNN) to find an optimal route, this method can enhance the MANET's survivability and usability [18].

- Priya Mankotia1 and Er.Amandeep Kaur presented an improvement in the AODV protocol which is done for the congestion avoidance in the network. The proposed technique is based on the back propagation algorithm in which error of each path is available from source to destination is calculated. The best path is selected which has minimum error or means that which has least chances of congestion in the network [19].

- Rashmi Chaudhary et al. offered a novel algorithm called SEAL. The new method is implemented on the AODV protocol. The selection of the optimal-path is based on multiple metrics such as hop count, remaining energy and routing load. The shortest path was ensured by the hop count, the less congestion was ensured by the routing load while the remaining energy ensures that the route validity was remained for a longer period. The pro-posed SEALAODV algorithm outperformed all the protocols so it improved the QoS metrics of the conventional AODV routing protocol [20].

- R. Thanuja & A. Umamakeswari proposed a new method for routing system that uses the hybridization of genetic algorithm with particle swarm optimization. This method is used for the Black Hole Attack (BHA) detection by using AODV routing protocol. This method utilizes the Data Routing Information (DRI) of the neighboring nodes, where the information of DRI is accumulated from each neighboring nodes which rise the accuracy of the probability of attack detection. The result of the new method improved the ratio of the throughput, reduced the routing overhead and end-to-end delay [21].

- Dr. Debika Bhattacharyya & Avimita Chatterjee introduced a novel approach to improve the energy of AODV routing protocol, which is used for discovering the optimal path between the nodes and for consuming the energy of the nodes. It utilized the packet size reduction to make the conventional AODV protocol more energy efficient [22].

- G. U. Mali & D. K. Gautam announced efficiently a novel method for evaluating the shortest-path in the wireless networks. The novel method is based on the delay in the real time during the response to the pool manager. This paper broadcasted a ‘“knock” message to estimate the real time routing delay from source node to any other nodes. Then used this delay for evaluating the shortest-path routing by the used of fuzzy logic [23].

- Dipika Sarkar et al. presented a new technique to select the route by combining AODV protocol with ACO for improving the Quality of Service (QoS) in the MANET. Ant colony
with AODV used a pheromone value of the path for selecting the finest route to deliver the data. The pheromone value calculation is based on the path reliability of end-to-end, hops count, congestion and remained energy of all nodes along that path. The proposed method selects the path with highest value of pheromone the data packet transmission [24].

### Table 5 Comparison of various ML techniques with Wireless NW

| References | Method                               | Enhancement                                                                 |
|------------|--------------------------------------|-----------------------------------------------------------------------------|
| [15]       | Combined modified Dijkstra and OSLR  | Multiple paths are enabled in network topologies.                            |
| [16]       | Fuzzy logic and Ant colony           | Improves the Quality of Service (QoS) such as high ratio of data packet delivery in the low end to end delay |
| [17]       | Fuzzy logic                          | Solves the uncertainty issues due to mobility, enhances the parameters of performance: packet delivery delay, packet delivery ratio and control overheads |
| [18]       | Hopfield Neural network              | Finds the optimal route, enhances the end to end average delay, packet receiving rate and routing recovery frequency |
| [19]       | Back propagation Neural network      | Avoids the congestion,                                                    |
| [20]       | SEAL                                 | Reduces the congestion, enhances QoS (throughput, delay)                    |
| [21]       | Practical swarm and Genetic algorithm| Improves the secure routing mechanism and improves the reduction at end-to-end delay and routing overhead |
| [22]       | Reduce the packet size               | reduces the energy consumption                                             |
| [23]       | Fuzzy logic                          | Finds the shortest-path route in real time wireless network                  |
| [24]       | Ant Colony Optimization (ACO)        | Improves Quality of Service (QoS)                                          |

7. Basic Workflow for machine learning in networking

Here are the basic steps for enhancing the NW, see figure 6:

**Input:** routing algorithms

**Output:** adaptive routing algorithms

Step1: Selecting routing algorithm and determining one for the wired and wireless network, in this paper the selected algorithms are Dijkstra routing algorithms for the wired network and AODV routing algorithm for the wireless network.

Step2: determining and understanding the problem.

Running the selected routing algorithms and analyzing them for determining the drawbacks. Then studying the algorithm from all directions and identifying the common points in wired / wireless routing protocols in term of efficiency which includes a decreasing energy consumption and increasing network life time for data relay, time, complexity, effectiveness which include quality of services (Qos) such as delay, jitter, offered bandwidth, packet loss, loop, freezing, throughput, overhead, communication cost.

Step3: converting the problem to mathematical models.

To easily deal with it, the problem get converted to equations.

Step4: solving the problems using machine learning.

First determining the problems, then selecting the machine learning techniques according to the type of problem.

Step5: Applying machine learning techniques.

Step6: evaluation.
The evaluation will be done by comparing the modified routing algorithms with the original algorithms.

![Diagram showing the basic steps for NW enhancement using ML](image)

**Figure 6** the basic steps for NW enhancement using ML

8. Conclusion

In this survey, we have made an exhaustive study on wired/wireless routing protocols. This studies is based on the enhancement methods that are used by wired/wireless routing to improve the capacity and resource utilization of the network.

This research attempts to focus on the enhancement of various protocols in both wired & wireless network. There are different shortcomings in these protocols, therefore, there are some difficulties for choosing the best protocol for different circumstances, also there are various challenges that need to be met in the network, and consequently, in the future they will be used broadly.
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