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Quality of Service of Routing Protocols in Wireless Sensor Networks: A Review

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ABSTRACT Due to distributed nature, dynamic topology and resources constraints of tiny sensing nodes in wireless sensor networks (WSNs), the quality of service (QoS) support is a challenging issue. However, satisfying the stringent QoS requirements is an open problem. QoS aware protocols for WSNs have gained recently considerable attention of the researchers. In this paper, we focus on the QoS satisfaction in WSNs, basics of QoS support in WSNs, and more importantly challenge, requirements of QoS at each layer. Furthermore, we review the QoS protocols and categorize the QoS aware protocols and elaborate their pros and cons. We also discuss the QoS parameters with respect to each protocol performance parameters. A survey and comprehensive discussion on the QoS aware protocols of WSNs are presented, including their strengths and limitations. Finally, we also survey some computational intelligence (CI) techniques and find the basic requirements of such techniques. Moreover, we study these CI techniques in the light of QoS management and tabulate the level of each CI technique for QoS management. The paper is concluded with open research issues.

INDEX TERMS WSNs, QoS, QoS aware protocols, computational intelligence techniques (CI).

I. INTRODUCTION

The WSNs are defined to be wireless networks composed of a very large number of interconnected nodes which can sense a variety of data, communicate with each other and have computation capabilities. The sensors are usually deployed into the scattered area, known as sensor field. These sensors gather data from an environment and forward it to the Base Station (BS) through multi-hops. The BS, also known as the sink, usually communicates with the users through a satellite or an internet connection [1].

Due to diverse and a wide range of applications Wireless Sensor Networks (WSNs) have gained considerable attention in recent years. Advances in miniaturization technologies, especially in Micro-Electro-Mechanical Systems (MEMS), have made it possible to develop Multi-functional Tiny Smart Sensors (MTSE). The MTSE now utilize WSNs and are envisioned to completely replace their conventional networks with WSNs. This will enable WSNs to become an integral part of human lives.

The WSNs based on their applications can be divided into two main categories i.e. tracking and monitoring [2], [3]. Monitoring application includes inside and outside environmental monitoring such as industrial unit and development monitoring, seismic and structural monitoring, physical condition monitoring and control monitoring. Tracking applications include vehicles, humans, animals and tracking objects.

They can also be deployed for a collection of various types of data mentioned above in almost every kind of physical environments such as plain, underground and undersea sensing fields. In every situation, a sensor network gets constrained differently depending on an environment. Some of such networks are described and explained in and the references therein [2].

However, WSNs are still facing many challenges such as limited power, bandwidth, mobility and no central controller.

The performance of any network including WSNs can be gauged, predicted and improved once the parameters characterizing the network are determined accurately. These parameters of a network include availability, bandwidth, latency, and error rate. Methods and techniques used to determine the parameters are known as Quality of Service (QoS).

At the present stage, WSNs need more attention in QoS provisioning making it a hot issue in current research.

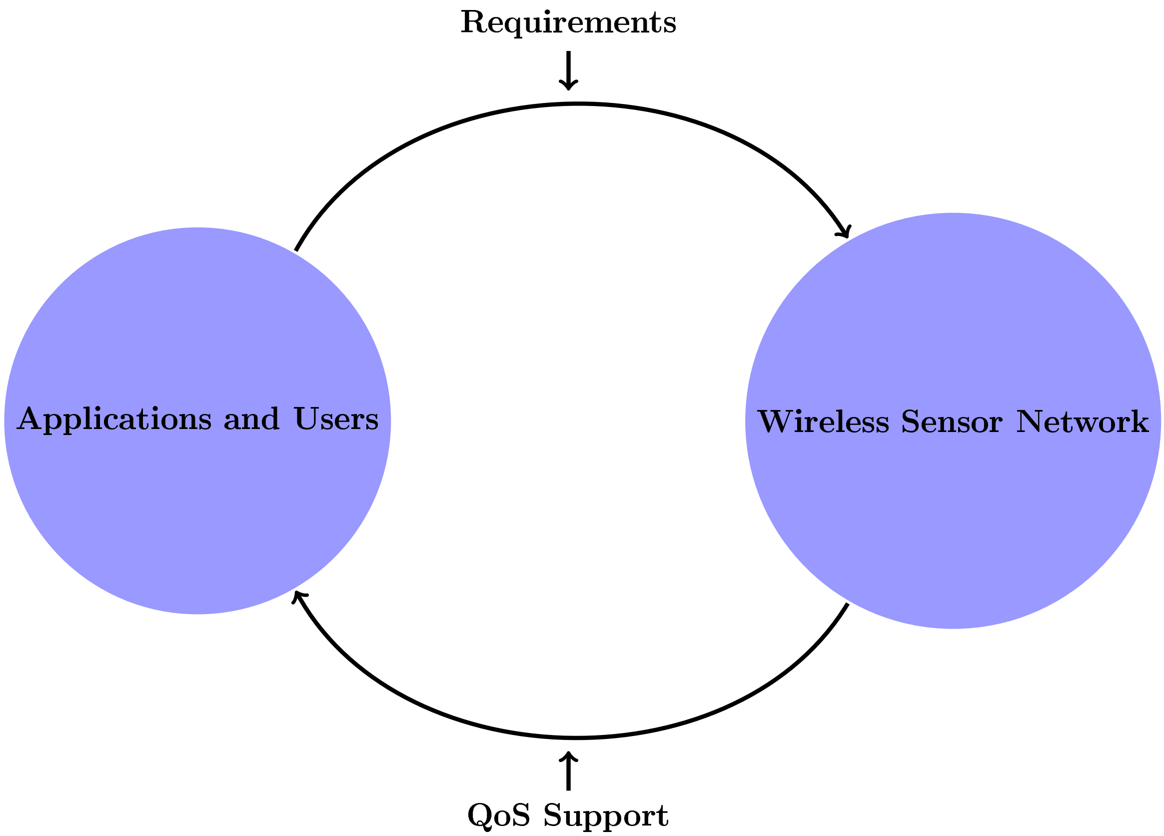

FIGURE 1. Requirements and QoS support for WSN.

However, incorporating QoS is not an easy task usually due to a large number of nodes involved in the network [4], [5]. Some of the important aspects like energy protection, protocol designing, and architecture in WSNs are explored in details but still QoS support issues need more attention [6].

In figure 1, a simple model shows that more users can always be included in the networks given that users are satisfied with the services of the network. Hence, the basic objective of the networks is how to utilize the network resources that provide QoS to users.

The rest of this article is planned as follows. In section I-A we present a short summary of the QoS in WSNs while in section II we tabulated QoS-aware protocols designed for WSNs with their advantages, disadvantages and QoS parameters. Comparison and evolution of proposed protocols are made in section III where we have described briefly computational intelligence techniques for QoS managements. Final section IV includes conclusion and some new suggestions.

A. QUALITY OF SERVICE

In this section, we provide a detailed analysis of QoS parameters of routeing protocols developed for WSNs. We have, however, included references which have a significant impact on the development of the research area. In the following, we give first a brief account of QoS and then describe each protocol selected for this study. In next section, we tabulate all the protocols giving their year of publication, main advantages and shortcomings if any and list of QoS parameters. As mentioned in the general introduction the network's capability to offer superior services is measured as Quality of Service of the network [7]. The basic objective of QoS is to guarantee that network has the ability to provide the expected results. Some of the basic QoS parameters are the delay (latency), throughput, energy consumption and error rate. It differentiates the traffic flows in the network by treating packets differently based on their nature. It's patterns perform diverse responsibilities based on the path of network traffic and site of the device performing the QoS functionality [8]. It also prioritize different data flows to ensure a certain level of performance. However, factors like the probability of missing data in networks, reliability and latency undermine the QoS [9]. QoS can achieve the following tasks.

- Provide high-level services in multimedia applications like video, audio and images or VOIP.
- Differentiate various network traffics and then assign priority for each traffic class and thus provide organized treatment of network resources.
- The network resources such as bandwidth are utilized efficiently.

1) QoS IN TRADITIONAL NETWORKS

A traditional network attains QoS support via traffic engineering or over-provisioning of resources. To provide such guarantee in computer networks two services differentiation models are used. One is planned for conventional wired computer networks such as Integrated Services (IntServ) and another one for Differentiated Services (DiffServ). IntServ, also called reservation-based approach, maintains services on per flow basis. In this approach, the network resources are assigned according to the application of QoS requirements. The IntServ establish virtual dedicated links between source and destination [11]. DiffServ, also called reservation less approach, maintains service on per packet basis. QoS is achieved in this approach through particular QoS methodologies such as queuing mechanism, admission control, and traffic class and policy managers [12].

2) QoS IN WSNs

WSNs are used for a wide range of applications and each application has its own QoS requirements such as delay sensitivity, energy and network lifetime. QoS is an umbrella term for a group of technologies that permit network-sensitive applications to demand and receive expected services levels in terms of QoS requirements [13]. In WSNs, QoS requirements can be specified from two perspectives [14]. One is called Network Specific QoS and other as Application Specific QoS. In application specific, each application has different QoS parameters such as data truthfulness, aggregation delay, fault tolerance and exposure [15], [16]. However, in WSNs every class of application also has some common requirements. So the network must fulfil the QoS needs when transmitting the sensed data from sensor field to the sink. Various data delivery models are used such as continuous, query and event driven [17]. Each model has its own QoS requirements. The basic QoS issues in WSNs are described below in details [6], [17].

1. Limited resources and capabilities: The WSNs have limited resources such as partial memory, bandwidth, power and processing capabilities. So QoS must be aware of them and there should be a balance between QoS level and energy level consumption.
2. Node deployment: The sensor node deployment is an important and difficult issue in WSNs. Since the deployment may be regular or random and proper deployment solves the QoS requirements, therefore the system must be aware of this issue.
3. Dynamic network topology: This issue mostly occurs in mobile WSNs, because the sensor nodes move in various directions. The QoS method must be aware of the node's power and link failure due to its mobility.
4. Scalability: QoS should not be affected by the increment or decrement in the number of sensor nodes in WSNs.
5. Multi-source Multi-sink: Depending on the application, the topology may have multi-source and multi-sink. So WSNs shall be able to maintain the diversified level of QoS supports.
6. Various traffic types: The sensor nodes may generate various types of traffic so the QoS process should be the equally efficient through max out and low traffic periods.
7. Less reliable medium: The WSNs medium is radio. It may be affected by different environmental factors such as noise and cross-signal interference.
8. Redundant Data: Sensor nodes are densely deployed so the generated data may be redundant. It causes the energy wastage; therefore it should be taken into the description in QoS.

There are various QoS parameters and services required for different applications. For multimedia or real-time applications, the QoS metrics are jitter, latency and bandwidth. While the military applications have the security QoS parameters, the emergency and rescue applications have the availability QoS parameters and the applications such as cluster communication in meeting hall have a little energy QoS parameter. Unlike the traditional wired network, the QoS requirements are more unfair by the resources constraints of the nodes. Buffer space, processing power and battery charge are the examples of resource constraints [18]. QoS provisioning in individual layers depends on layer capability, so for performance evaluation and QoS assessment each layer has specific parameters that are used. The table below 1 shows the list of parameters in each layer [14].

B. QoS IN WSNs SECURITY

Security in WSNs is one of the major issues because of its applications in the military. The military application may generate sensitive data or operate in hostile unattended environments like a battlefield. Protection of sensor data from adversaries is an unavoidable need. To address such issues the effective QoS mechanism is needed. The famous example is real-time target tracking application such type of application requires specials QoS security technique. Another example is the health monitoring application.

QoS can effectively enhance the security of the WSN. Sensor network transportation must avoid exposure. To achieve QoS in the sensitive applications the following shall be provided. Security services shall provide information secrecy, data integrity and resource availability for users. The three parameters model such as reliability, availability and serviceability can effectively improve the security of the WSNs.

C. QoS AWARE TECHNIQUES DESIGNED FOR WSNs

In Figs. 2 and 3 we have shown the distribution of study of WSNs, and of different QoS parameters in WSNs over the recent years. In the following, we outline a comprehensive review of quality of service aware routeing protocols in wireless sensors networks and mention some issues and problems and their possible solutions.

1) DELAY vs. RELIABILITY

Delay in the data transmission across the WSNs can adversely affect the reliability of data transmission. To solve this issue many protocols are suggested by researchers. In the following, we outline some major contributions.

TABLE 1. QoS parameters for different layers.

Name of the Layer	QoS Parameters
Application Layer	Data consistency, Detection chance, Data originality, Reply time and system life time
Transport layer	Rate, Delay, Medium and reliability
Network layer	Power efficiency, Routing strength, Bottleneck chance, Routing protection and path delay
MAC layer	Power effectiveness, Communication reliability, Throughput and range of communication
Physical layer	Communication, Data processing and sensing components

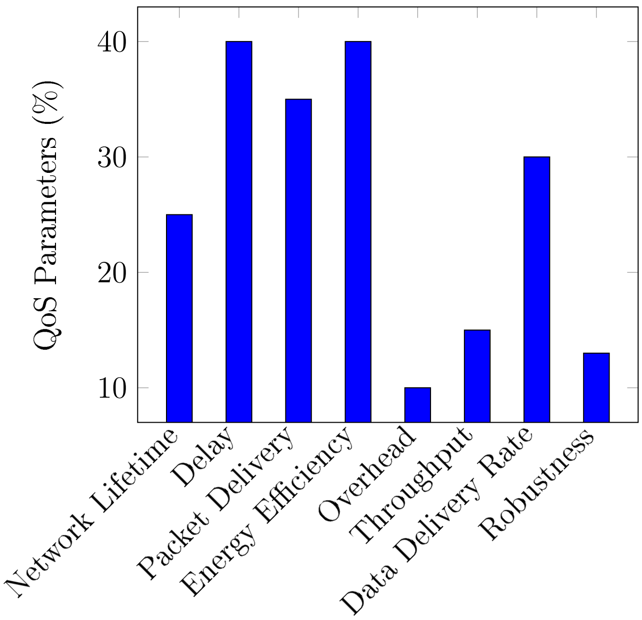

FIGURE 2. Distribution of QoS parameters in the literature over the recent years.

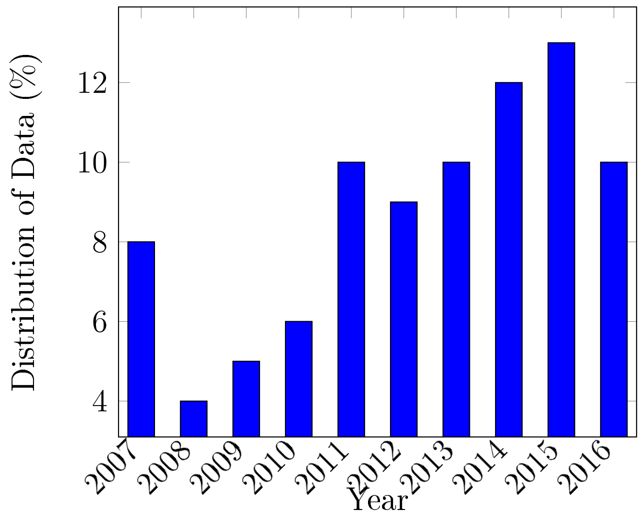

FIGURE 3. Distribution of literature over the recent years.

a: DACR

Razzaque *et al.* [19] have presented a detailed survey of cooperative routeing issue. To solve the problem authors have proposed the protocol called DACR (Distributed Adaptive Cooperative Protocol). Delay energy aware routeing (DEAR) design principal is based on AODV with a little modification of control packets i.e. a route is discovered from source to destination by selecting best relay from the set of candidate relay nodes. The DACR exploits the cooperative communication on top of the energy awake and delay to optimize the tradeoff between the delay and reliability through lexicographic optimization at each hop. To determine the best relay with the small amount of overhead the DACR employs computational intelligence (CI) method called light weight reinforcement learning method to update the routeing nodes with information expected that could be provided by the candidate relay node. The DACR selects such convey node that provides with relatively high reduced delay and reliability towards the target node to manage such system the DACR use the multi-objective lexicographic optimization (MOLO) approach.

Simulation of DACR performances is done in NS-2 for a wide range of data traffic generation rate and link failure rates with respect to various performance parameters such as reliability and delay. The simulation outcomes illustrate that DACR outperforms a number of states-of-the-art protocols. The DACR achieves the less delay and good reliability and its computation cost is low. The most important advantage of DACR is less overhead. It achieves the QoS parameters such as network lifetime, delay and reliability under versatile network environments. The proposed framework is useful for many applications because its computation cost is low. However, the DACR does not consider the throughput and reliability parameters for performance and its performance in mobility environments is also not very good.

b: EAQRP

A similar protocol is developed by Akkaya and Younis [20] using the so-called queuing model to differentiate the real time and non-real time traffics (QMDT). Their protocol is designed to achieve QoS parameters such as minimizing delay and improve network throughput. It uses the K-least cost path algorithm to select the most reliable route for transmission based on traffic types.

c: QARP

In [21] a protocol with similar properties has been developed which can be used for the delay sensitive applications. This delay aware routeing protocol is developed to manage the WSNs with mobile base sink. It achieves the reduced end-to-end delay and high packet delivery ratio.

The proposed protocol also considers the reliability parameters. The NS-2 results show the high reliability in transmitting data to multiple base stations. The proposed protocol is most suitable for the real-time applications.

d: CRSN

Liang *et al.* [22] have discussed the channel allocation and overload issue for the real-time applications and considered the designing of WSN. It is based on cognitive radio scheme to achieve the QoS (CRSN). In this algorithm, channel mechanism is and two types of switching are used. One is periodic switching (PS) and the other is triggered switching (TS). The simulation results show that the proposed protocol achieve high QoS in real-time traffics.

2) DATA DELIVERY RATIO AND NETWORK ROBUSTNESS

In every network, each end user tries to achieve high Data Delivery Ratio (DDR) but in the large networks achieving high DDR is difficult. There is also a need for protocols that can balance features such as power effectiveness, scalability, robustness and provisions of timeliness.

a: ROL

To achieve these requirements, Hammoudeh and Newman [23] proposed a new protocol called Route Optimization and Load balancing (ROL). It is a clustering protocol that group nodes into clusters. It makes the routeing paths to be based on localized metrics that are linear in the number of nodes and links, which makes ROL energetically and computationally efficient. In the set-up phase, the clusters are formed and when the cluster builds round end then transmission phase starts. Cluster head receives data from the node and the aggregated data is relieved to sink (Base Station) using CDMA code. Each node uses TDMA scheme for transmissions. The ROL provides robustness through multipath routeing and implements the energy efficient sleep/wake scheduling of S-MAC to save energy. To achieve greater energy saving, the sleep and wake schedule in integrated with the TDMA means the radio is on when transmitting and off when not. To reduce sleep latency it has a sporadic receive-send cycle and uses sleep/wake scheduling. Optimization instrument for balancing the communication resources for the constraints and precedence of user applications has been developed and nutrient flow based distributed clustering (NDC) an algorithm for load balancing is developed. The proposed algorithm facility is flawless with any clustering algorithm to equalize as far as possible diameters and memberships of clusters. When the ROL/NDC implements the experiment results that demonstrate ROL/NDC gives a superior network lifetime then another scheme. The ROL/NDC maintains a highest of 7% variations from the best cluster population. It reduces the total number of set-up message by up to 60%, and also reduces the end-to-end delay by up to 56% and increases the DDR by up to 98% compared to MIRE++. The ROL is distributed protocol so it is useful for large networks and scalability is the basic feature. Energy consumption is less and load balancing and robustness are good. The main shortcoming of ROL is that it does not consider the parameters such as power spending, reliability and throughput. It is not suitable for the centralized network. The efficiency of the algorithm under variable traffic load is decreased because of sleep and listen periods are predefined and constant.

b: QoSR

Levendovszky and Thai [24] proposed a similar protocol named as Quality of Service Routing Protocol (QoSR) which achieves QoS parameters DDR and network robustness. QoSR aims to receive the successful packet to extend the network lifetime and uses the Bellman-Ford algorithm which determines the optimal route from source to sink nodes.

3) DELAY vs. PACKET DELIVERY RATIO

Delay in the data transmission across the WSNs can also adversely affect the packet delivery ratio of data transmission. To achieve high QoS we need to minimize the delay and maximize the packet delivery ratio.

a: QoS-PSO

Liu *et al.* [25] have addressed the routeing problem. However, the algorithm is not useful in sustaining the active character of WSNs and cannot guarantee enough QoS in WSNs applications. To solve this problem, a new agent assisted QoS based routeing algorithm for WSNs, QoS-PSO is developed. This algorithm is used for the synthetic QoS model to increase the QoS level of WSNs. To select the best route, this model applies the synthetic QoS parameters as the objective function of PSO. The initial path for PSO can be provided through agent based routeing. Each node in the network creates and maintains a routing table for all other nodes and built several paths among the source and target node. When a node wants to transmit data, it first builds a route with target node so that it starts agent based routeing discovery process such as forward agent is generated by the source node. Once the path is found, the forward agent reaches the target node and the onward agent is converted to the reverse agent. The reverse agent then follows the route of the forward agent broadcasting and in the meantime adjusts the node routeing table, approved according to the network condition. This procedure is called multi-agent based route finding. QoS-PSO algorithm is implemented in NS-2 and the outcome illustrates that the proposed protocol makes sure superior QoS in WSNs in terms of packet loss and latency. QoS-PSO algorithm is scalable and is developed for the large-scale WSNs. With increased size of the network, the proposed approach achieves the less packet ratio and less delay. The main shortcoming of PSO algorithm is its inability to provide throughput, power spending and reliability parameters for analysis. Control overhead is large in the route discovery process which causes the energy consumption. Routeing table maintained is also overhead on a node. The PSO algorithm routeing discovery is good for real time traffic transmission.

b: QRPWMS

Ghaffari and Takanloo [26] introduced a QoS-based routeing protocol for wireless multimedia sensor network (QRPWMSN) that incorporates QoS parameters e.g. delay, energy efficiency, and reliability for multimedia applications. QRPWMSN uses a genetic algorithm and a queuing theory for selection of a route.

c: RPRA

The similar evaluation of QoS parameters is also done in [27]. Using the packet injection rate the routeing performance is evaluated through the novel parameter known as routeing pressure without simulation. QoS parameters delay and packet delivery ratio are also evaluated for testing the performance.

d: MMQARP

In [28] a multi-constrained and multi-path QoS-aware routing protocol (MMQARP) is developed. It takes The QoS parameters such as link reliability and energy efficiency, that can be used for delay sensitive applications are considered. It requires reliable and energy efficient path for communication.

4) DATA DELIVERY RATIO vs. CONTROL OVERHEAD

The QoS parameters such as delay and packet loss when transmitting the video and imaging data in Wireless Multimedia Sensor Networks (WMSNs) require more attention when selecting the route for transmission. In the route selection, the control overhead must be kept low because more control overhead causes waste of energy. To address these issues many protocols have been proposed.

a: AntSensNet

It is proposed by Cobo *et al.* [29] for ant-based routing. The proposed QoS routeing model for WMSNs is based on the conventional ant-based algorithm. QoS requirements build a hierarchical structure on the network before choosing a suitable path. To achieve minimum video distortion transmission, the AntSensNet is able to use an efficient multi-path video packet scheduling. Architecture works in 3-steps it builds clusters nodes into colonies first and then finds networks path between clusters using ant. Lastly, it finds, element forward network traffic by means of the routes before discovered by the ants. For the selection of Cluster Heads (CHs), it uses special agents (ants) in totally distributed manner. Each sensor node broadcasts a HELLOİ packet and stores such information in the table. The stored information is used then to decide how to join cluster and route discovery. After this stage, the sink releases control messages into the networks. The AntSensNet uses the queuing model for the traffic services differentiation. When a sensor node wants to send some information to the sink, such information is directly sent to CHs then it checks the routeing table to select the appropriate route for further transmission. To find such route AntSensNet uses various ants also called control packets such as backward ant (BANT), forward ant (FANT), routeing maintain ant (MANT) and data transmission ant (DANT). The experiments of video transmission mechanism, routeing algorithm and clustering process is done in NS-2. The benefit of this protocol lies in the reality that it provides assurance for both types of traffics but performance results show that it is more appropriate for real-time traffic because it reduces the delay and maximizes the DDR ratio. The algorithm achieves scalability and also improves the data aggregation mechanism due to the hierarchical structure. The main drawback of the algorithm is it does not consider the QoS parameters such as energy and throughput. The control overheads are large in the routeing process. The multi-path assignment is also an issue.

b: ProHet

A similar protocol is also developed by Xiao *et al.* [30] called the probabilistic routeing protocol for heterogeneous sensor networks (ProHet). It works in two phases, first one is called preparation phase that identifies the neighbour relationships and determines the reverse path for the asymmetric links, and the second one is a routeing phase. Low overhead with a guaranteed delivery rate is the characteristic of ProHet.

5) DELAY vs. ENERGY

Delay in the data transmission across the WSNs can cause the unnecessary energy consumption of data transmission.

a: InRoute

The work in [31] introduced InRouteİ- A QoS-aware route choice protocol for engineering WSNs with the goal of satisfying reliability requirements. It selects the optimal route based on the network condition and application. It uses Q-learning method which satisfies the industrial applications. QoS requirements are Packet Error Rate (PER), delay and energy. The function of Q-learning is to select and execute the route based on the reward. The received reward updates the Q-value. InRoute uses reward function based on QoS metrics energy and PER. To find an optimal path towards the destination, it uses the exploitation and exploration strategy. It searches all feasible paths to a destination on a round robin basis for a partial number of the round then to select optimal route used *e*-decreasing strategy. It is proved that the protocol results are better as compared to the traditional protocols. The proposed protocol meets QoS requirements that are required for the industrial applications to achieve good DDR ranging from 4% to 60% and also the control overhead ratio is small as compared to traditional protocols. InRoute is capable of assuring application packet error rate. It is energy efficient and balances the energy consumption. It is a competent protocol in terms of control overhead. The main shortcoming is that it does not consider the QoS metrics such as energy spending on sleeping or ideal listening as the power spending is openly linked to the MAC protocol.

b: ECMP

In [32] a similar protocol is introduced called energy constrained multi-path routing (ECMP). Its basic objective is to reduce energy consumption and minimize delay. It utilizes bandwidth more efficiently.

c: PDORP

In [33] the problem of delay and energy consumption in the routeing process is incorporated in the suggested protocol. Authors have designed the hybrid optimization based PEGASIS-DSR optimized routeing protocol (PDORP). It uses the directional transmission and cache concept. High throughput and reduced delay are the achievements of the PDORP.

6) DELAY vs. THROUGHPUT

Wireless multimedia sensor networks are less delay tolerant networks and require hard QoS requirements. Delay in the data transmission across the WMSNs can affect the throughput of data transmission.

a: QoSMOS

Cross-layer QoS architecture for WMSNs called QoSMOSİ is proposed by Demir *et al.* [34], which addresses the QoS requirements for WMSNs. It takes into account the services differentiations in terms of delay, reliability and throughput domains. The authors have proposed cross-layer QoS architecture that unifies network and link layers into single communication module for QoS provisioning. QoSMOS as a cross-layer services differentiations architecture supports traffic classifier, scheduling and services provision with its unified communication module XLCM. Several ES-PNBs are implemented in XLCM with respect to various QoS parameters. XLCP is also developed within XLCM and it is based on the QoSMOS architecture. XLCP utilizes unified routeing and MAC layer functionalities to create ES-PNBs. The detailed experiments are conducted to analyze the performance of the protocol. From the results, it is obvious that XLCP is capable of services differentiation in delay, reliability and throughput domains. In the first experiment, the effect of buffer length on QoS is provided. In the second experiment, various time slots are considered. Results show that time slot length has a major effect on average delay, throughput and per packet energy overhead QoS differentiation. XLCP helps to provision and differentiating QoS for different levels of services classes. XLCP has scalable services differentiation in WMSNs. It successfully differentiates services class in terms of soft delay, reliability and throughput domains. The XLCP throughput and Delay QOS in congested networks are not good. Frame exchange sequence in XLCP involves much control overhead which causes waste of extra energy.

b: WASN

In [35] a protocol for WASNs that selects a route for different traffics is developed. This route is assigned based on traffic parameters providing low latency and reliable delivery in the presence of failures.

c: MWTP

In [36] organization of a sensor node in sensor field and the route of the sensor towards the sink which achieves the minimum delay in transmission is developed. Authors have proposed the energy-efficient homogeneous clustering algorithm. It chooses the cluster head periodically. For the routeing, it uses the Dijkstra's shortest path algorithm. It attains the reduced packet delay and minimum energy consumption.

d: QARM

Han *et al.* [37] have designed the algorithm that is based on the software-defined networking (SDN). It determines the detection of the link and QoS requirements of the flow. The results show that it increases the throughput and reduces the delay for video traffics.

7) DATA DELIVERY RATIO vs. ENERGY CONSUMPTION

WSNs are resources constrained networks because of low power backup, therefore, extra energy consumption in data transmission across the WSNs affects the packet delivery ratio of data transmission.

a: BLOOM FILTER BASED QoS

To enable QoS guarantee in WSNs, bloom filter-based work-flow management is created by Tong *et al.* [38], which addresses the issue of effective work-flow management in WSNs. Since the implementation of workflows in WSNs is usually hierarchal so a dynamics oriented QoS, effective and efficient hierarchal work-flow management mechanism is necessary. To provide this mechanism a bloom filter based hierarchal work-flow management model is introduced, which coordinates both the atomic services level and the node level of guaranteed workflow QoS. The bloom filter based method tries to achieve work-flow adaptation on both the atomic services level and node level. Work-flow management model is devoiced using four main features like QoS monitoring, the planner, the services level adaptation and the node level adaptation. The services level CBF is used to maintain the set of current normal atomic services and the node level BF is constructed to maintain the set of attributed strings of the current nodes. QoS degradation is located with the help of the services level CBF and the node level BF. The function of the planner module then coordinates the services level and the node level adaptation to guarantee workflow QoS again. The proposed approach is implemented in Java and two stage experiment is done. In the first stage experiment, QoS monitoring efficiency is checked. In general, with a longer running time, proposed approach can statistically achieve better performance than the static approach in terms of the QoS detecting delay and the QoS monitoring cost. In the second stage experiment, the space complexity and energy efficiency is tested. The results show that the proposed approach is useful. It also achieves a greater success ratio to guarantee work-flow management approach. Bloom filter based approach QoS monitoring mechanism can achieve shorter degradation delay with less monitoring cost. It has time and space efficiency and more energy efficient especially, for the large data set. The main shortcoming of the proposed approach is the longer detection delay.

b: GEAR

In [39] a protocol named as Geographical and Energy Aware Routing (GEAR) is introduced. It uses the geographical information while selecting a route for traffic. The basic objective of the GEAR is to select energy efficient route that achieves good data delivery ratio.

c: ACOFTR

Surendran and Prakash [40] have proposed a bypassing void routeing protocol. Being based on virtual coordinates this protocol prevents the void problem which arises from the source to target. In particular, it analyzes the delay issue of the routeing.

8) OVERHEAD vs. LATENCY

Large routeing overhead in the data transmission across the WSNs can effect latency of data transmission. For large routeing overhead in the route selection, it uses extra channel for transmission which then uses extra energy and also causes more latency in networks.

a: 2ASenNet

In [41], the issue of suitable routeing which is the rising order for a real-time application in WSNs, has been prepared'' QoS based communication protocol ''2ASenNet''. Artificial Fish Swarm Optimization (AFSO) and Ant Colony Optimization (ACO) both are combined into the 2ASenNet protocol which discovers and maintains route between sink and CHs. The proposed protocol is particularly designed for WSNs using multiple QoS metrics. In this protocol, CHs are created first and then route between CH and sink is discovered for transmission. Ant's algorithm is used for routeing''discovery and scheduling policy is used for different traffic classes. In route discovering, it follows the ACO and AFSO methods. The simulation is conducted in NS-2 and the experiment outcome is compared with AODV and traditional AntSensNet. The delivery ratio and delay performance of proposed protocol is better than others. The 2ASenNet gets the minimization of power. The proposed approach packet delivery ratio is good as compared to others and it is most suitable for multimedia applications. However, it does not consider the parameters such as throughput, energy and reliability. Routeing overhead is large which causes waste of energy.

b: RSEP

Poojary and Pai [42] have designed a protocol called Reed-Solomon Encoding protocol (RSEP) to achieve QoS objectives such as power awareness, reliability, and having low latency. It works in two phases for selection of a route for transmission. First one is route setup phase and other one is a data transmission phase. The proposed protocol uses Reed-Solomon encoding to encode the transmitted data.

c: P2PGDR

Shen *et al.* [43] have also proposed a similar protocol for hybrid networks that selects a route with the high throughput and low control overhead. To do this peer-to-peer (P2P)-based Market-guided Distributed routing mechanism (MDR) is used.

Diaz *et al.* [44] have proposed the QoS based protocol for wireless multimedia sensor networks (WMSN) and the proposed protocol is based on the ad hoc cluster based architecture. The proposed protocol considers the issue of cluster creation that achieves the QoS for WMSN. The experiment results show that proposed protocol achieves the end-to-end QoS for each multimedia stream.

9) SCALABILITY vs. ENERGY

Scalability in WSNs can have also adverse effects on the energy consumption of data transmission in the network.

a: QOMOR

In [45], a QoS-aware MAC protocol QOMORİ using best retransmission for the types of sensor networks called intra-vehicular sensor networks is designed. It minimizes the delay in transmission and minimum number of retransmission are required in delivery phase when each sensor node is part of a QoS group. To resolve this issue, theoretical analysis of the single QoS set is offered and it is extended to multiple QoS set. In the frame delivery to keep the optimum number of retransmission, the algorithm is also given for the QoS sets. The main benefits of QOMOS are the reduction of receiver hardware, decreases the cost of the sensor nodes. It is light weight and easy answer for one hop sensor networks because of one mode communication of the data and lack of synchronization. The main shortcoming of QOMOR is when frame size increases, then achievement of the good delivery ratio with strict delay constraints under intense networks becomes a problem.

b: MCP

Another similar protocol is designed by Sanchez *et al.* [46] called Multicast Routing Protocol (MCP). This protocol achieves energy efficiency and is based on multicast routeing specially designed to minimize the total energy used by the multi-cast tree in case of the scalability.

c: HHR

Jie *et al.* [47] presented the routeing protocol for the Information-Centric Network (ICN) with similar settings. It is based on hybrid scheme and its routeing structure can be divided into three main parts such as Local Routing (LR), Delivery of Local Publication to Core domain (DLPC), and Remote Publication Routing into edge domain (RPR). The deployment of the HHR is very fast.

10) THROUGHPUT vs. DELAY

To achieve high throughput multi-path route selection is a good choice but it faces a delay issue because the route is divided into multi-channel which becomes congested and the result is more delay.

a: QEMH

Mazaheri *et al.* [48] proposed a QoS based and energy aware multipath hierarchical routeing algorithm in WSNs called QEMH. It optimally tackles the problem of QoS, improves throughput and delay, consumes less energy and prolongs life time in sensor networks. It uses a hierarchical method that assures QoS requirements with the small amount of energy. The distance to sink, signal to noise ratio, remaining buffer size and residual energy criteria must follow when cluster CH is created and the route is discovered. The QEMH considers the end to end delay and energy consumption parameters. It combines the idea from previous protocols in order to optimally tickle down the difficulty. QoS-QMEH works in three phases such as the formation of CH and then pathfinding phase and lastly fixing numerous paths between CHs and sink. The cluster head detection is based on two parameters, node residual energy and node distance to sink. In the route discovery phase, the link cost metrics is used which includes link performance factor, buffer size and energy factor. This protocol uses multi-path model jointly with Forward Error Correction (FEC) method to get well from node failure without invoking network-wide flooding for pathway finding. It employees the queuing model for real-time and non-real-time traffic handling. The proposed protocol is implemented in NS-2 and evaluated with the MCMP and EAP protocol under different network conditions such as the impact of arrival rate, node failure probability and a number of nodes but the experimental results show that QEMH achieves good delivery ratio, long network lifetime, and power saving, less delay then other protocols. The main benefits of the QEMH are; it differentiates the non-real time traffic and real time because it uses queuing model. The delay and throughput performance is good because of using multi-path routeing. It minimizes energy consumption due to hierarchical methods. Congestion is more on the CHs. Multi-path routeing and multi-path assignment may become an issue sometimes.

b: SNDMRP

In [49] a protocol called secure node disjoint multipath routeing protocol (SNDMRP) is developed which uses the digital signature cryptosystem to transmit the data packets for security purposes. Their proposed protocol can improve the packet delivery and reduces the end-to-end delay.

11) ENERGY CONSUMPTION vs. RELIABILITY

a: PCDST

Peng *et al.* [50] addresses the issue of unnecessary energy consumption during transmissions and reliability of the network because WSNs are resources constrained, so a new cross-layer communication protocol is proposed to resolve the issue. It is named as directed spanning tree based power control (PCDST). It together with routeing layer MAC and physical layer effectively balances the energy consumption and reliability of the network. This algorithm follows S-MAC concept in the decision of the power levels. Directed spanning tree protocol is used to stabilize the power spending. It uses the geographic information for the tree construction. The cross-layer protocol sets a directed path for data transmission through the network based on the power control scenario and geographic information. Based on the prime-dual algorithm, a Lagrange dual function is designed and optimal solution set of transmission power is deduced. To check the efficiency of the developed algorithm, the simulation is done in NS-2 and the performance is compared with the minimum energy spanning tree (MEST) and geographic random forwarding (GeRaF). PCDST shows good performance in extending network lifetime and improves the network throughput. The experiment results show that PCDST can decrease the overall power spending of the networks. PCDST has good performance in extending network lifetime and also good throughput of the network communication. PCDST is scalable but as the number of the nodes increases, the energy saving feature increases as well. The main shortcoming of PCDST is that it does not consider the QoS parameters such as delay, overhead and reliability. Its performance is not suitable for the small networks.

b: ERDTP

Morita *et al.* [51] have proposed a routeing protocol for WASNs that have the ability to differentiate the traffics and then assign the route for transmission accordingly. The proposed protocol has characteristics of low latency and reliable delivery in the presence of failures.

c: SPMR

Frechette *et al.* [52] have developed a protocol that has robust network design. The proposed algorithm is based on the capped hose model to survey a series of traffic scenarios. This algorithm has two findings one is design based on multi-hub routeing and the other is a mechanism for finding the route based on the cost effectiveness. It achieves the high data delivery ratio.

d: MDTRP

In [53] a protocol based on the ant colony algorithm is introduced. Based on the ant colony it avoids the waste of resources and achieves the routeing reliability. It uses the multidimensional tree route scheme so the route is more robust.

e: QEMPAR

In [54] algorithm for real time applications called Energy Aware Multi-Path Routing Algorithm (QEMPAR) is given. It uses the energy consumptions model that finds the energy aware route for the transmission.

f: EEMCRA

To improve the network energy efficiency with high demand of user issue is discussed in [55]. To address this issue authors have proposed energy consumptions model which are based on link loads, and use the network's bit and called it Energy-Efficient Minimum Criticality Routing Algorithm (EEMCRA), The experiment results show that proposed model achieves the less energy consumption in routing discovery phase.

g: GQOR

Jun and Wei [56] have discussed the issue of to finding the tradeoff between energy efficiency and QoS consideration. To improve the reliability of the data transmission the opportunistic routing is the basic need of QoS. To achieve this author proposed the Grid-based QoS-aware Opportunistic Routing shortly called GQOR. It will first use the node location information to split the networks into virtual grid. The experiment results show that GQOR achieve high reliability and reduced delay.

12) CONTROL PACKETS vs. ENERGY CONSUMPTION

A user reserves a route for transmission by first sending control packets which leads to extra consumption of energy.

a: MQoSR

Alwan and Agarwal [57] suggested a multi-objective QoS routeing for WSNs . It addresses the issue of discovering a route that assures the multiple constraints for QoS routeing. The multi-objective or multi-constraints routeing decision is an issue in WSNs. MQoSR protocol for WSNs addresses this issue by considering the quality parameters for both the links and the paths. It uses the HELLO message in which, the link condition is reported and the link cost function is calculated through greedy forwarding approaches. Now the route request phase is started and the total cost function of the route is determined such as a cost of the required QoS and link cost. To do so, it broadcasts RREQ message to its entire neighbourhood. The MQoSR reselect the path and checks the path condition and required QoS. In the protocol, the sink uses multi-path routeing and erasures coding. Once the sink selects the path then reply to sensor nodes though RREP message that travel on the selected disjoint routes. The experiment was done in C++ and the performance was compared with the MCMP model. The performance is evaluated under special scenarios and the experimental outcomes show that proposed algorithm can achieve the application requirements in terms of reliability way under the variation of the link weights in selecting a single or multiple paths. The proposed algorithm achieves better performance with respect to routeing overhead, delay, data delivery, energy consumption as compared with MCMP and MQoSR. The network lifetime improves due to energy efficient solution. It provides multi-objective QoS routeing for special applications. MQoSR achieves the less delay and good data delivery ratio due to optimal routeing selection. The routeing overhead is less. The reliability is good due to multi-path routeing. The main shortcoming of MQoSR has maintained routeing table is overhead. In routeing, control packets are involved which consumes extra energy.

b: EARTP

In [58] a similar protocol called EARTP for real-time traffics that selects energy aware route for balancing node energy consumption to prolong the network lifetime is designed. The proposed protocol considers the QoS parameters, routeing and delay and enhances the reliability.

c: TRRP

In [59] the protocol is designed with a solution for robust path issue for the multi-hop wireless networks. This algorithm is good for large size wireless sensor networks with lossy links.

d: EERP

Ghaffari [60] addresses the issue of energy and prolonged network lifetime. To achieve them a protocol called energy-efficient routeing protocol (EERP) is designed. It is based on the A-Star algorithm it selects the optimal shortest path based on the buffer occupancy, link quality and residual energy of next node. Testing results show that proposed protocol improves network lifetime.

13) LATENCY vs. ENERGY CONSUMPTION

a: EQSR

Efficient and QoS-aware multi-path routeing protocol EQSR [61] that addresses the issue of QoS requirements such as medium and latency constraints for diverse QoS based applications of WSNs. It follows the method of the Directed Diffusion (DD) in the path discovery phase, it uses link cost function to select next hop. It also uses KEEPALIVE message to save energy which keeps multiple paths alive and updates cost function parameters such as link quality. Remaining buffer size and reduced energy are added to the data packets. When EQSR constructs the path for transmissions, it notes the signal to noise ratio, route buffer size and residual energy to predicate the next hop. It selects the route based on traffic types such as real or non-real traffic. To handle both types of traffics, it uses the queuing model. FEC method follows a multiple path routeing''. To distribute the traffic amongst the multiple paths according to delay requirements, the EQSR divides the data messages into segments of the same size, add correction codes and then transmits it over multiple paths. It uses the multi-path routeing scheme for the transmission based on the directed diffusion. The data transmission is more secure because of the use of the special code method such as FEC for encoding. The throughput analysis of the EQSR is good. EQSR is good for query-based'' data delivery but more processing power is involved in the multimedia data transmission. Hence EQSR is not best for multimedia sensor networks.

b: LLP

Hu *et al.* [62] have developed a protocol (LLP) that is based on the anycast communication paradigm. The proposed protocol achieves the QoS parameters such as reduced end-to-end latency and energy consumption.

c: MWTP

Gupta and Bose [63] have addressed the energy efficiency issue. To save the power consumption and prolong the network lifetime they have developed two residual energy-aware joint routeing and power allocation strategies.

d: CASER

In [64] energy and security are considered mainly for the multi-hop wireless networks. It proposes the secure and efficient Cost-Aware Secure Routing (CASER) protocol. It selects the route for transmission that is energy aware and authentic for transmission. It achieves the tradeoff between routeing efficiency and energy balance.

e: ONOCR

In [65] the collision issue in routeing is taken care off. They have designed to decrease collision possibility using cooperative routeing in WSNs and developed the mathematical model. It uses the branch-and-bound algorithm for routeing searching. The testing results show that algorithm reduces the collision ratio.

f: DJRRO

In [66] the resource allocation and optimal routeing which can cause the energy consumption are considered. The cross-layer technique increases the energy efficiency of the network. It works on alternating direction method of multipliers (ADMM). The mathematical analysis shows that the proposed method is faster. It achieves! the low overhead and robust operation.

14) MOBILITY vs. DELAY

In sensing field a sensing node can move away for some period of time, and receiving node waits till the time it comes back to the original place causing a delay in data transmission and reception.

a: RACOON

In [67], this issue of the mobility of the networks and priority scheme for medical applications are addressed. Network mobility of Wireless Body Area Networks (WBANs) introduces unnecessary inter-networks collision and power dissipation. Multi-user QoS protocol called Random Contention Resources Allocation (RACOON) is proposed to solve the problem. It overcomes the WBAN mobility issue and satisfies the inter WBAN QoS requirements. The proposed algorithm is a medium range system fixed in MAC layer for multi WBAN QoS. Random based inter CPN negotiation and resources allocation of CPN based are the two main parts of RACOON. Control overhead of inter WBAN QoS is solved by RACOON. The decision of resources allocation between WBAN is done through random value comparison between WBANs. The RACOON chains an active QoS modification in mobile WBANs; it considers the critical level differences. It decreases the energy consumptions through hierarchy CPN/WSN resources allocation and uses the probing base inter WBAN interface detection method to detect the collision. The issue of WBAN mobility and inter WBAN QoS requirements are simultaneously satisfied by RACOON. It is tested in MATLAB and the outcomes are compared with the QoS and the results of the experiment show that RACOON has improved QoS in terms of transmissions latency, power consumptions and user capacity. It considers the priority scheme for medical applications which is very important in medical data transmission. It overcomes the performance poverty caused by WBAN mobility. The RACOON provides better power control and delay performance. It does not consider the throughput and reliability parameters for performance. However, its performance is not tested in the large networks.

b: HydroCast

Lee *et al.* [68] have proposed a protocol called HydroCast. It takes the node mobility into consideration which enhances the propagation delay performance and energy consumption. It takes the wireless channel quality into consideration to improve the routeing performance under continuous node movement conditions.

c: ABR

In [69] the mobility is incorporated in the protocol through the ant base algorithm. In this algorithm for the route selection the link quality and link, the delay is estimated for each pair of nodes. It uses the space division multiple access techniques.

d: LRAGR

Rao *et al.* [70] focus on the cluster formation and mobility management. It consists of the two phases, clustering phase and the other is a routeing phase. It uses the energy efficient neighbour discovery protocol (ENDP) at the MAC layer. Low latency and reliability are the achievements of this protocol.

e: ACO

Y. Dawood Al-Ani and Jochen Seitz discussed the QoS issue in routing in case of the node mobility [71]. To address this issue authors have designed a routeing protocol that is based on the ant colony optimization (ACO) algorithms. The NS-2 simulation results show that the proposed protocol achieves the well performances in high mobility.

15) DELAY vs. RELIABILITY

a: QPRR

In [72], cooperative routeing is explored in time unreliable WSNs. The achievements of QoS guarantee are in the domains of reliability and delay. CoSenS is a MAC protocol that addresses the issue of services differentiation in multi-hop WSNs. It also solves QoS in Carrier Sense Multiple Access/Collision Avoidance based WSNs. Proposed algorithm Collect then Send burst Schemeİ abbreviated by CoSenS, is implemented on top of CSMA/CA to defeat its weaknesses. Its architecture is simple, a router does not transmit packets as they arrive but, it first collects all packets from sensor nodes. The collection time period is called waiting period (WP), this improves the reliability, delay and throughput. All these traffics are queued in the router. The gathered data in the WP are then transmitted in bursts. In transmission, it follows CSMA/CA rule and this time is called transmission period (TP). To schedule all traffic more efficiently, the CoSenS uses two other in fixed priority schedules. Event driven and periodic traffics are the types of traffics considered by the CoSenS. It is implemented in OPNET for experiments and the results are compared with IEEE 802.15.4. The experiments results show that CoSenS self-adopts to the traffic variation and really improves latency, reliability and Deadline Meet Ratio (DMR) for critical traffic while not demeaning best traffic as compared to IEEE 802.15.4 using the scheduling policies. No synchronization is required between nodes, so the CoSenS is scalable protocol. The proposed protocol performs well in congested networks when delivery services data quickly, the sink is more significant. DMR, delay and reliability are the features of CoSenS. In transmission process control, overhead are large. Energy consumption is also large. The packet scheduling process is not simple.

b: CTPP

In [73] a similar protocol called (CTPP) is designed where latency issue in constructing a minimum energy data aggregation tree is incorporated. The balanced binary tree where initially the sink node finds the nearest two sensors nodes as its children, and then each child identify another two nearest nodes called children nodes. Minimum latency and power are the quality of the proposed protocol.

c: EARB

In [74] the reliability and energy consumption issues for medical application are undertaken. Authors have developed a routeing protocol for low-power and lossy networks. It selects the route based on the remaining energy and uses the expected transmission count metric. It reduces the energy consumption and increases the network lifetime.

d: PC-GA

In [75] power control and QoS issue for the smart grid applications are considered. A heuristic algorithm is designed that allocate the channel dynamically, and the traffic is differentiated based on priority. Reliable transmissions and low latency are the features of the proposed algorithm.

16) SCALABILITY vs. RELIABILITY

In WBSNs to add some extra sensor nodes to achieve the required QoS actually, reduces the reliability due to the scalability of nodes.

a: QPRR

In [76], proposed a protocol called QPRR. It addresses issues in medical applications like the mobility of patient in the hospital for transmission, efficient routeing and reliable communication of patient data in real time. It uses energy aware paring routeing protocol (EPR) which considers the QoS metrics such as energy availability and geographic information of the devices. It is used for choosing the best next hop for the ordinary packet (OP). To select an efficient path from source to a target node, QPRR chooses the next hop. It introduces the route reliabilities of all likely routes from the source to target node and determine a number of duplications for sending RSPS. QoS-aware queuing module (QQM), Routing Services Module (RSM), Hello Packet Module (HPM), Packet Classifier (PC), Reliability Module (RM) are the four basic modules of QPRR. It is implemented in OMENT based simulator Castalia and the performance is compared with DMQoS. The experimental results show that QPRR improves DDR, reduces network traffic weight, reduces power consumption and lowers latency. The QPRR achieves 88% reliability and achieves the good scalability. Routeing table maintainer is also an issue. It does not consider the throughput parameters for performance.

b: DPRS

In [26] a similar protocol (DPRS) for real-time traffic called energy aware dual-path routeing scheme is developed. It balances nodes energy consumption to prolong the network life, and routeing delay is minimized because it considers the network congestion and enhances the reliability by introducing minimal data redundancy.

c: SRP

In [77] the scalability of the network routeing is undertaken. The properties considered are the shortest path routeing, separation between the class of policies and the memory size of the path.

d: EAMRP

In [78] the reliability and delay for WSNs are studied. To solve these issues energy aware multi-path routeing scheme is designed. For the transmission phase, one primary path and number of alternate paths are built. Reduced delay, high throughput and less energy consumption are the features of the EAMRP.

e: QRPWMS

In [58] a protocol that uses the genetic algorithm and queuing theory for determining the best efficient routeing path is developed. It is more useful for the multimedia traffics. Reliability, energy efficiency and reduced delay are the features of this protocol.

17) CONTROL PACKETS vs. ENERGY CONSUMPTION

A user for reserving a route for transmission first sends control packets which lead to consumption of extra energy and channels.

a: QA-SFSD

Siddarth and Seetharaman [79] addresses the services discovery issue in MANETs with routing protocol called (QA-SFSD). They have studied and pointed out that offered mobile services finding approaches do not totally address the issue of service choice and the robustness. To solve these issues, they have proposed a methodology of cluster based QoS-aware services discovery architecture using CI technique, swarm intelligence. The swarm intelligence is used to establish the Intra and inter-cluster shortest path routeing. When Cluster Head (CH) receives client request of service then every CH finds the server which satisfies the QoS constraints. The CH forwards request to other CH using Swarm Intelligence (SI). Finally, QoS aware server is chosen and it replies to the clients. The proposed algorithm is tested in NS-2 and the experiment outcomes are compared with Real Time Database QoS-aware services selection (RTDQS) protocol and non-QoS-aware services infrastructure. The results are compared with others and found that the proposed protocol can get better DDR. Delay and energy consumptions of the proposed protocol are better than RTDQS and non-QoS-aware services infrastructure. Less energy consumption, reduced delay and good success rate are the features of the proposed protocol. Routeing overhead of the proposed protocol is more. It does not consider the throughput, overhead and reliability parameters for performance.

b: QEAR

In [80] a routeing protocol that achieves the QoS parameters such as congestion control, minimizing delay, and maximizing throughput is developed. In the selection of the optimal path four metrics i.e. distance between nodes, residual energy, traffics priority and link quality are taken into account. All nodes compute their priority with respect to sink. Based on this priority and other metrics each node finds two forwarding nodes, namely, main forwarding node and alternate forwarding node. The buffer occupancy identifies the congestion. The priority of the traffics are then divided into different colours which show the priority level such as green, yellow, and red. The overhead issue can arise in this protocol.

c: MGNR

In [81] an algorithm that is based on the game theoretic model and used for the multi-objective optimization problem. It uses the Nash bargaining framework which solves the tradeoff between energy efficiency and load balancing.

d: MER

In [82] another algorithm that considers the issue of energy consumption and physical layer security is designed. For the security, achievement authors have used the cooperative jamming technique. The results show that energy consumption level is very good.

e: XLQACF

Shah and Lozano [83] have designed two algorithms for minimization of the energy consumption namely a Fixed-Tree Relaxation-Based Algorithm (FTRA) and a very efficient Iterative Distributed Algorithm (IDA). They optimize the route selection and achieve the energy saving metric.

18) SCALABILITY vs. CONGESTION

Scalability in the WSNs can create congestion of data transmission. For large networks, congestion is a critical issue.

a: Indoor-LBS

Jeong *et al.* [84] studied the traditional centralized location based services (LBS) which have the problem of traffic congestion and low scalability. They have then developed architecture called a site based self-organizing and completely spread network infrastructure. The proposed indoor LBS platform is adapted to support reliable and efficient services to users or mobile devices in dynamic indoor environments. The proposed SoSP network structural design is comprised of SoSP router. It represents the unit space and it contains four components i.e device proxy, resource manager, SR-Manger and the services agents. A user can easily request any indoor LBS from the physical resources with a mobile device using its wireless communication. Robots can also collaborate with other robots using wireless communication through SoSP router. It uses NSPQ-based services lookup and binding algorithm that searches for the shortest physical path to the nearest services resources. The proposed algorithm is compared to the traditional centralized architecture in the experimental evolution of scalability and real test bed environments. In the first experiment, the scalability is tested. When the number of lookup increases, the proposed lookup engine with NSPQ is highly efficient over time. Data transmission is also tested, the proposed algorithm guaranteeing the soft real-time QoS. It enhances scalability, decentralized fairness and robustness. Indoor LBS platform achieves the following features. It requires no centralized knowledge. The scalability level is good and it requires the zero configurations. Personnel privacy level is also good. The main shortcoming of this approach is that it does not consider throughput, energy consumption, delay parameters. This approach is not good for the small networks.

b: PPT

In [85] a routeing protocol for the purpose to select short path called Pheromone Termite Model (PTM) is designed. To establish a route the proposed protocol uses termite-based concept. Packet generation rate and pheromone sensitivity are the two new features introduced by PTM. Avoiding the congestion and extending the network lifetime are the features of the proposed protocol.

Surendran and Prakash [40] have proposed the algorithm for routeing that is based on the ant colony algorithm. The proposed algorithm first learns the characteristics of the network then selects the route. The proposed algorithm is best for secure data transmission. Reliability is the main advantage of this protocol.

c: ARACC-RP

In [86] reliability and congestion are considered. To address these issues authors have designed congestion control algorithm and adaptive reliable scheme. It makes use of the multi-path routeing scheme. Testing results show that it achieves the high throughput with reduced packets drops and overhead.

19) THROUGHPUT vs. DELAY

To achieve high throughput multi-path route selection is a good choice but the multi-path route selection faces a delay issue because the route is divided into multi-channels which become congested and results in more delay.

a: ZEQoS

In [87] the QoS energy aware based Body Area Network (BAN) routeing that addresses the QoS issue in BAN communication such as reliability and delay control for different traffic types. It considers three types of data for the indoor hospital environment with the improved ability to handle mobile nodes communication, are reliability sensitive data, delay sensitive data and ordinary data. ZEQoS introduces MAC and network layers modules and three algorithms such as neighbour routeing table construction, table constructor, and route selector. MAC receiver, reliability module, delay module and MAC transmitter are the four basic modules of MAC layer. The network layer consist of four modules such as Packet Classifier (PC), Hello Packet Module (HPM), Routing Services Module (RSM) and QoS-aware queuing module (QQM). Proposed routing protocol ZEQoSİ provides a mechanism with the help of neighbor table constructor algorithm, routing table constructor algorithm and route selector algorithm to calculate the communication cost and end-to-end paths delays and end-to-end path reliabilities of all possible paths from source to destination and then decides best possible paths with the consideration of QoS requirements of the Ordinary Packet (OP), Reliability Sensitive Packet (RSP), and Delay Sensitive Packet (DSP). The experiments and testing environments are carried out in OMNET++ based simulator Castalia. The generated results are compared with DMQoS and no routeing protocols. The experimental results show that ZEQoS achieves better performance in terms of throughput, fewer packets dropped on MAC and network layers and lower traffics than comparable protocols including DMQoS and no routing. ZEQoS achieves the good throughput, reliability and delay requirements of BAN communications. It is good for the services differentiation. The main shortcoming of ZEQoS is that it does not include the delay and overhead parameters. Power spending is more because routeing overhead is more and table maintainer is also an issue.

b: ACOLBR

In [88] a similar protocol called Ant Colony Optimization based Load-Balancing Routing Algorithm (ACOLBR). It is a biologically inspired hierarchical routeing algorithm. It uses the minimal spanning tree (MST) algorithm. Minimum end-to-end delay, load balancing and prolong network lifetime are achievements of ACOLBR.

c: SAAR

In [89] algorithms considering high throughput in multi-hop networks is designed. These algorithms are called spatial reusability-aware single-path routeing (SASR) and any path routeing (SAAR) protocols. Reusability of media is the feature of these algorithms.

20) POWER CONSUMPTION AND RELIABLE DATA TRANSMISSION

a: XLArch

In [90], the issues of power consumption and reliable data transmission services that provide QoS guaranteed transmission of data in WMSNs are taken care off. The cross-layer (X-layer) structured is designed with multi-path routeing in WMSNs. The cross-layer architecture maintains the shared database which contains all layers information. It also applies the priority for traffic such as real-time traffic has the highest priority. It also specifies a services excellence model and a services excellence level depending on traffic pattern. This protocol also enables the use of multi-paths when delivering the data and selects the path according to the priority of the packets. This architecture reduces delay and packet loss and increased the transmission rate.

b: CDSSMAN-ETS

Asif *et al.* [91] have proposed an algorithm that uses the multi-channels for transmission. A channel is assigned to a node on the basis of node ID. Minimum end-to-end delay and high throughput, less energy consumption and reliable transmission are achievements of the proposed protocol. The main benefits of the proposed protocol are to achieve less delay chance, low packet loss and high packet transmission rate. This algorithm improves the reliability of sensor networks. It requires more intelligent scheduling algorithm.

c: ORA

In [92] the energy consumption issue for WSNs is analysed. To address the issue the opportunistic routeing algorithm that

TABLE 2. Comparison of QoS aware routeing protocols.

Protocol Name	Year	Advantages	Disadvantages	QoS Domains Analyzed *Proposed protocol performance is analyzed with respect to parameters given below*						
				Net-work Life time	DDR	Robu-stness	Delay	Ener-gy Level	Over-head	Thro-ug-put
DACR [20]	2014	DACR attains both delay guaranteed data delivery and reliability in WSNs and increases the network lifetime.	In the mobility case, the DACR performance is not good and the throughput analysis in big scenarios is not up to the mark.	Yes	Yes	No	Yes	No	No	No
EAQRP [21]	2003	The proposed protocol provides high throughput and less delay for the real-time traffic.	It is not good for the non-real- time traffic. It does not consider QoS parameters for performance evolution.	Yes	Yes	No	No	No	No	Yes
QARP [22]	2016	The proposed protocol is good for the delay sensitive applications.	It is not good for the random deployment of the sensor nodes.	Yes	No	Yes	No	No	No	No
CRSN [23]	2011	Good for real-time traffics in case of handoff issue.	It does not consider the QoS parameters for performance evolution.	Yes	No	No	No	No	No	No
ROL/NDC [24]	2013	It can provide QoS in domains such as network lifetime, DDR and network Robustness. ROL/NDC is useful for large networks.	Due to hierarchal and structural issues, the bottleneck problem has more chance to arise. It is not useful for centralized networks.	Yes	Yes	Yes	No	Yes	No	No
QoSR [25]	2015	It selects the optimal route based on the power level for transmission using bellman ford algorithm.	Its control overhead ratio is more in the route selection.	No	No	Yes	Yes	No	No	No
QoS-PSO [26]	2012	QoS-PSO algorithm is scalable and achieves good performance in terms of less delay and good packet delivery ratio in large networks.	Due to the overhead energy cost is likely to be more than other protocols. Control overheads are larger in route discovery.	No	Yes	No	Yes	Yes	No	No
QRPWMS [27]	2011	In the route selection the QRPWMSN uses the queuing theory and genetic algorithm to select the optimal route.	The proposed protocol considers only the multimedia traffic. The starvation issue may arise in traffic differentiation.	Yes	No	No	Yes	Yes	No	No
RPRA [28]	2015	It is more suitable for the large size network because it avoids the congestion through providing more paths for transmission.	It does not consider the energy consumption metric for evolution.	Yes	No	Yes	No	No	No	No
MMQRP [29]	2014	Useful for the delay sensitive applications such as audio, video transmission	It uses the multi-path routeing approach so it requires an intelligent algorithm for channel assignment.	Yes	No	Yes	No	No	No	No

TABLE 2. ***Continued.*** **Comparison of QoS aware routeing protocols.**

AntSensNet [30]	2010	It comprises both reactive and proactive schemes. It achieves QoS metrics such as maximum delivery ratio, less delay and low overhead. It also offers different classes of traffic.	Control overheads are more in the routeing process which causes extra energy waste.	No	Yes	No	No	No	Yes	No
ProHet [31]	2013	The basic feature of the ProHet is to send acknowledgments to the sender for successful transmission.	Route selection phase is complicated so energy consumption level is high.	No	No	No	Yes	No	Yes	No
InRoute [32]	2012	It achieves QoS parameters such as energy, delay and PER which is the basic need of industrial applications.	Energy consumption is large and it is scalable for large networks	No	Yes	No	Yes	No	No	No
ECMP [33]	2008	It reduces the congestion because of use of the multi-channels for communication. Channel utilization is good.	It divides the channel into multi-channels. The main issue is how to assign the channel to a node.	Yes	No	No	No	Yes	No	No
PDORP [34]	2016	It can be applied to many applications which require the reliability and energy efficiency such as underwater monitoring.	Not good for the dynamic environment.	Yes	Yes	No	No	Yes	No	No
QoSMOS [35]	2013	Scalable service differentiation in WMSNs is main feature. It successfully differentiates service classes in terms of soft delay, reliability and throughput domains.	In highly loaded networks it is unable to meet end-to-end delay requirements. Frame exchange sequence in XLCP involves much control overhead.	No	No	Yes	Yes	Yes	No	No
WASN [36]	2006	Traffic type priority is a feature of the proposed protocol. So channel utilization is good.	It is not good for the low priority traffic.	Yes	No	No	Yes	No	No	No
MWTP [37]	2015	Performance is good for the large scale networks. Energy consumption is less.	Bottleneck issue may arise when the network size is large.	Yes	No	Yes	No	Yes	No	No
QARM [38]	2012	Algorithm is good for the delay sensitive, bandwidth sensitive and best effort traffics.	Take the requirements of only multimedia traffics.	Yes	Yes	No	No	No	No	No
Bloom Filter based QoS [39]	2014	It has shorter degradation detection delay with less monitoring cost. The QoS degradation locating mechanism has time and space efficiency. Energy efficiency is also good, especially for large data set.	It has low energy of sensor nodes or the congestion of a wireless channel access.	No	Yes	No	No	Yes	No	No

TABLE 2. ***Continued.*** **Comparison of QoS aware routeing protocols.**

GEAR [40]	2001	Energy aware routeing is characteristics of GEAR. It uses the geographical information for the route selection.	To collect the geographical information for routeing selection the control overhead becomes an issue.	No	Yes	No	No	Yes	No	Yes
ACOFTR [41]	2015	It is good for the secure data transmission and fault tolerance is the basic feature of this protocol.	It requires the most authentic technique for security. The energy level is not appropriate.	No	Yes	No	No	Yes	No	Yes
2ASenNet [42]	2012	It can provide QoS requirements in terms of delay and DDR of wireless multimedia sensor networks. It achieves two main goals of reducing of power consumption by using virtual CH formation for data transmitting and getting advantages of ACO and AFSO.	Routing overheads are more in route discovery processes.	No	Yes	No	No	No	Yes	No
RSEP [43]	2014	Security is the basic feature of this protocol because it uses the Reed-Solomon encoding to encode the transmitted data	To encode the data before transmission it requires some intelligence technique.	Yes	No	No	Yes	Yes	No	No
P2PGDR [44]	2015	Routing scheme is good for the hybrid network. A market-based policy to support cooperation incentives is the feature of the proposed protocol.	Chances of delay are more when the traffic ratio is increased.	No	Yes	No	No	No	Yes	No
QOMOR [46]	2007	Due to lack of coordinator and one way transmission of the data the QOMOR is simple solution for one hope sensor networks.	In large networks good delivery ratio with strict delay achievement is difficult when the frame size is increased.	No	NO	Yes	No	No	No	No
MCP [47]	2007	Scalability is the attribute of the proposed protocol. It is better for the multicast communication.	Not good for unicast and broadcast communication.	No	No	No	Yes	Yes	No	No
HHR [48]	2015	It is very good for the mobility environment and can be applied to a large scale network. Deployment is usually fast.	Energy consumption and routeing maintains is the big issue in this protocol.	Yes	No	No	No	No	No	No
QEMH [49]	2012	Energy consumption is comparatively small, throughput and delay performance is good because it uses multiple paths.	Clustering brings extra overhead so it is not appropriate to network deployment in large region.	No	No	No	Yes	No	No	No

TABLE 2. ***Continued.*** **Comparison of QoS aware routeing protocols.**

DSMRP [50]	2002	It is good for the military like applications for security purpose because it uses digital signature cryptosystem to transmit the packet.	To encode the data before transmission it requires some intelligence technique.	Yes	Yes	No	No	No	No	Yes
PCDST [51]	2014	It improves the throughput of network communication. Increasing the number of nodes in the networks causes the power reduction.	PCDST does not consider the QoS parameters such as delay, energy, reliability and overhead. It is not suitable for small networks.	No	No	Yes	No	No	No	No
ERDTP [52]	2007	The ability to differentiate the traffics and then assign the route for transmission. It is good for the high priority.	The channel assignment to traffic is not defined.	Yes	Yes	No	No	No	No	Yes
SPMR [53]	2015	In the robust network design, the performance is very good. It is also good for the real time traffics.	It is based on the tree routeing structure so bottleneck problem may be possible.	No	No	Yes	No	Yes	No	No
MDTRP [54]	2012	Minimum number of hops in routeing are the feature of this algorithm.	Energy consumption is large.	No	Yes	Yes	No	No	No	No
QEMPAR [55]	2011	It increases the network lifetime for the real time applications.	It does not have the mobility support.	Yes	Yes	No	No	Yes	No	No
MQoSR [58]	2013	It provides multi-objective QoS routeing for diverse applications. It achieves QoS parameters in terms of routeing overhead, delay, DDR and energy consumption.	Control packets are involved in routeing process.	Yes	Yes	No	No	No	Yes	No
EARTP [59]	2006	It selects the energy-aware route for the real-time traffic that achieves the low delay.	It is good for real-time traffic and not for all types of traffics.	Yes	No	No	Yes	No	No	No
TRRP [60]	2016	It provides the robust route construction so it is good for the large scale networks.	In routeing path construction, the energy consumption ratio is high.	No	No	No	No	No	Yes	No
EERP [61]	2014	It improves the network life-time using A-Algorithm.	It does not consider the QoS parameters for performance evolution.	No	No	Yes	No	Yes	No	No
EQSR [62]	2010	It maximizes the network life-time through balancing the energy consumption across multiple nodes. It uses services differentiation to delay sensitive traffic and provides less delay and good throughput due to use of multiple paths.	It cannot achieve the delay requirements when the load is increased. It can be used for continuous data delivery or event driven applications.	No	Yes	No	Yes	Yes	No	No

TABLE 2. ***Continued.*** **Comparison of QoS aware routeing protocols.**

LLP [63]	2005	It provides the low latency in any cast communication paradigm.	The performance of proposed protocol is not good for the multicast and broadcast communication.	Yes	No	No	No	Yes	No	No
MWTP [64]	2015	In routing process the energy consumption is less. Performance is good for the multi-hope networks.	It does not consider the QoS parameters for performance evolution.	No	No	No	No	Yes	No	No
CASER [65]	2015	It is better for the secure traffic transmission. Energy consumption level is good.	Require intelligent security algorithm.	Yes	No	Yes	No	Yes	No	No
ONOCR [66]	2016	Relay node allocation and optimal power management is the feature of proposed algorithm.	It does not consider the QoS parameters for performance evolution.	No	No	No	No	No	Yes	No
DJRRO [67]	2013	It minimizes the transmits power though cross-layer techniques. Low overhead and robust nature is feature of this.	Not good for the mobility management.	No	No	No	No	No	Yes	No
RACOON [68]	2011	It considers the priority scheme for medical applications such as medical data transmission. It solves the WBAN mobility issue and achieves better power control and low latency.	It does not consider the throughput and reliability parameters for performance. Performance is not tested in the large networks.	No	No	No	Yes	Yes	Yes	No
HydroCast [69]	2016	HydroCast provides low latency in case of mobility. Energy consumption is less.	Overhead is more.	Yes	No	No	No	Yes	No	No
ABR [70]	2010	Good for the MWSN. Reliability is the basic feature of this protocol.	Energy consumption level is not appropriate.	Yes	No	Yes	No	No	No	No
LRAGR [71]	2013	Performance is very good in the high mobile environment.	Cluster formation requires an intelligent algorithm to choose the cluster head. Bottleneck issue may be possible.	Yes	No	NO	No	Yes	No	No
QPRR [73]	2014	It is very interesting solution to the problem of sensitive data transmission in hospital environments. It can provide QoS guarantee in many parameters.	It may have overhead in routeing because routeing table maintaining is an issue.	Yes	No	Yes	No	Yes	No	No
CTPP [74]	2004	It assigns the channel based on traffic priority. Sleep and wake scheduling is basic features of this algorithm.	It requires the intelligent algorithm for management of wake and sleep scheduling of node.	Yes	No	No	No	Yes	No	No
EARB [75]	2014	Useful for the medical application and it increases the network life time.	It does not consider the QoS parameters for performance evolution.	No	No	No	No	Yes	No	No

TABLE 2. ***Continued.*** **Comparison of QoS aware routeing protocols.**

PC-GA [76]	2013	It is good for the multimedia traffics transmission.	It uses the priority algorithm so chance of starvation is possible.	Yes	No	Yes	No	No	No	No
CoSenS [77]	2012	No synchronization is required between nodes so it is scalable protocol. The proposed protocol performs well in congested networks. Dead line meet ratio (DMR), delay and reliability are the main features of CoSenS.	In transmission processes control overheads are large. Energy consumption is also large. The packet scheduling process is not simple.	No	Yes	No	Yes	No	No	No
DPRS [78]	2006	Dual-path routing scheme for real time traffic is the basic feature of the proposed protocol.	Energy consumption is more in routing selection.	Yes	No	No	Yes	No	No	No
SRP [79]	2015	More suitable for the large network w.r.t energy efficiency level.	Not consider the basic QoS parameters for performance evolution such as delay, DDR and soon.	No	No	No	NO	Yes	No	No
EAMRP [80]	2016	It uses the multi path scheme for transmission so it achieves the reduced delay, high throughput.	Channel assignment technique require intelligent algorithm for channel assignments.	Yes	Yes	No	NO	Yes	No	No
QRPWMS [81]	2011	It improves the transmission with less congestion.	It does not have the mobility support.	Yes	Yes	No	NO	No	No	No
QA-SFSD [82]	2013	A QoS aware service finding structural design satisfies the QoS constraints and achieves a less power consumption. Less delay and good DDR are main features.	Overhead in maintaining the table. Routing overhead (ants) are large.	No	Yes	No	Yes	Yes	No	No
QEAR [83]	2004	The route is selected based on the distance between nodes. Minimum distance is considered because the energy consumption is less.	Control overhead is large.	Yes	Yes	No	No	No	No	Yes
MGNR [84]	2015	This algorithm solves the tradeoff between energy efficiency and load balancing.	It will not consider the QoS parameters for performance evolution.	No	No	No	No	Yes	No	No
MER [85]	2015	It is more suitable for the secure traffic transmission. Energy consumption level is good.	It does not consider the QoS parameters for performance evolution.	No	No	No	No	Yes	No	No
XLQACF [86]	2013	It achieves the significant amount of energy saving in routing process.	It does not consider the QoS parameters for performance evolution.	No	No	No	No	Yes	No	No
Indoor-LBS [87]	2014	It requires no centralized knowledge. Its scalability level is good. It requires the zero configurations. Personnel privacy level is also good	It does not consider throughput, energy consumption, delay parameters. This approach is not good for the small networks. Maintaining routing configuration is overhead.	No	Yes	No	Yes	No	No	No

TABLE 2. ***Continued.*** **Comparison of QoS aware routeing protocols.**

PPT [88]	2014	It is good for the congestion avoidance because it uses the Pheromone Termite (PT) model for the route selection.	Computational cost is very high.	Yes	No	No	Yes	No	No	No
ARACC-RP [89]	2016	It avoids the congestion when the network size is large and provide the reliable rout for transmission.	It uses the multi-path so it requires intelligent algorithm that assign channel to traffics.	Yes	Yes	Yes	No	No	Yes	No
ZEQoS [90]	2014	It achieves the QoS parameters such as latency, higher throughput and less packets ratio.	Overheads are large such as it uses three algorithms in routing process.	No	Yes	No	No	Yes	No	No
ACOLBR [91]	2010	It is good for the distributed system because it uses the minimal spanning tree (MST) algorithm for routing.	Bottleneck issue may arise because of tree based structure.	Yes	No	No	Yes	No	No	No
SAAR [92]	2016	It achieves the maximum throughput in transmission. Reusability of media is the basic feature of this algorithm.	It does not consider the QoS parameters for performance evolution.	No	Yes	No	No	No	No	No
XLArch with multi-path routing [93]	2013	Less delay, good DDR and high transmission rate are the main features. This algorithm improves consistency of sensor networks	It is not implemented. It requires more intelligent scheduling algorithm.	No	No	No	No	No	No	No
CDSSMAN-ETS [94]	2010	Good for the congestion environment because it uses the multi channel distribution scheme.	Channel assignment algorithm is not intelligent.	Yes	Yes	No	No	No	Yes	Yes
ORA [95]	2015	It uses the opportunistic routing algorithm for the selection of energy aware route.	Not good for large scale networks.	No	No	Yes	No	Yes	No	No
ATGRS [96]	2015	It selects the relay node for routing based on the statistical analysis and stochastic geometry.	The main drawback is that it does not consider QoS parameters for the evolutions.	No	No	No	No	No	No	No
CNSMR [97]	2015	Good for the multicast transmission.	Not best for the broad cast communication.	Yes	Yes	Yes	No	Yes	Yes	No
HOCA [98]	2014	It avoids the congestion issue for medical application. High throughput and reduced end to end delay.	Require intelligent algorithm for channel assignment.	Yes	No	No	No	Yes	No	No

saves the energy in routeing phase is developed. The testing results show that it achieves high data delivery rate.

d: ATGRS

Bannaei *et al.* [93] presents the algorithm that considers the statistical investigation and stochastic geometry to read geometric routeing schemes. The proposed algorithm is based on the Marko decision. It uses the statical formulas in the selection of relay node.

e: CNSMR

Maddali [94] have designed a core network which supports multicast routeing (CNSMR) protocol. It comprises of the heterogeneous nodes. It achieves the high throughput and low latency and good channel utilization for the multicast environment.

Sarkar and Murugan [96] surveyed the routeing protocols for wireless sensor networks. In this survey, authors discuss the protocols with respect to QoS parameters. The mean

TABLE 3. Protocol comparison.

Protocol Name	Simulation Type	Comparison Protocol
DACR [20]	NS-2	AODV
ROL/NDC [24]	Dingo WSN	Mires++ and LEACH
AntSensNet [30]	NS-2	AODV and ASNS
InRoute [32]	OPNET	AOMDV and MRE-RSM
QoS-PSO [26]	NS-2	AODV and EEABR
QoSMOS [35]	NS-2	Geflood and MM-SPEED
Bloom Filter based QoS [39]	Java	Traditional Approach
2ASenNet [42]	NS-2	AODV and AntSent
QOMOR [46]	None	None
QEMH [49]	NS-2	MCMP and EAP
MQoSR [58]	C++	MCMP
PCDST [51]	Not specified	MEST and GeRaF
EQSR [62]	NS-2	MCMP
RACOON [68]	Not specified	WBANQoS
CoSenS [77]	OPNET	IEEE 802.15.4
QPRR [73]	OMNET ++ based simulator Castalia	DMQoS and No Routing
QoS-aware [82]	NS-2	RTDQS
indoor LBS [87]	Not specified	Centralized LBS
ZEQoS [90]	OMNET++	DMQoS and no routing
XLArch with multipath routing [93]	Not specified	Not implemented

weakness of this survey is that it does not show the pros and cons of each protocol.

Bhuyan and Sarma [97] surveyed the delay aware QoS routeing protocols for WSNs and checked the performance of these protocols in the grid and random deployment of the nodes. QoS parameters such as DDR and delay are analyzed in the NS-2 simulator.

Jadhav and Satao [98] have discussed the opportunistic routeing protocol(OPR) for WSNs. When a node wants to transmit the OPR selects the node which is closest to the target node for forwarding. It is most useful for the opportunistic communication. However, this survey does not discuss the pron and cons of each protocol.

In [99] the routeing protocols for body area sensor networks is studied. Authors have discussed the strengths and weakness of each protocol.

f: HOCA

Rezaee *et al.* [95] addressed the issue of congestion in medical applications routeing. Authors have proposed the data-centric congestion management protocol using AQM (Active Queue Managements). It uses the multipath routeing to avoid the congestion of traffics.

In [100] the simulation and the analytical model for the sensor nodes based on discrete time Markov chain (DTMC) is introduced.

In [101] the existing transport protocols are discussed. In the paper, authors studied the QoS parameters such as reliability.

In [102] surveys of QoS routeing protocols that are based on the swarm intelligence (SI) is carried out. SI is the intelligent techniques that find a path for transmission that is energy aware.

In [103] the issue of signal to noise ratio is discussed. Optimal power allocation and route selection are the basic need for optimization. It is argued that cooperative transmission is suitable for Optimal power allocation.

II. COMPARISONS OF QoS AWARE PROTOCOLS

In the table 2 we summarize the advantages and disadvantages of the QoS-aware techniques that we have discussed for the WSNs. The table 2 also shows the performance parameters.

III. OTHER CONSIDERATIONS IN WSN

In this section we discuss the simulation techniques, major methodologies and issues faced during management of QoS parameters.

A. SIMULATION SCENARIOS

For the computer science researcher to test and verify the proposed protocol in the simulation environment its very costly to deploy a complete test bid environment such as connect large numbers of computer, routers and switches etc. So in this modern technology simulation play a major role and it will save a lot of time and money of the researchers. Various simulators are used such as SensorSim, J-Sim, GloMoSim, SENS, TOSSIM, OMNET++, NS-2, MATLAB and OPNET. The below table 3 show the simulator use the researcher to test the proposed protocol as we study in literature.

TABLE 4. Computational intelligence techniques.

CI Approach	Computational Requirements	Memory Requirements	Flexibility	Optimality
Neural Networks Algorithm (NNA)	Average	Average	Best	Optimal
Fuzzy Logic (FL)	Average	Average	Best	High
Evolutionary Algorithm (EA)	Very High	Average	Best	Low
Swarm Intelligence Algorithm (SWA)	Low	Medium	High	Optimal
Artificial Immune System (AIS)	Medium	Problem Dependent	High	Near Optimal
Reinforcement Learning (RL)	Low	Medium	High	Optimal

B. QoS MANAGEMENTS ISSUES IN WSNs

The below table 4 show the various computational intelligence techniques that can be applied to various problem solution depending upon the nature of the problem. In table, we just show the rate ratio of various parameters such as memory requirements, process requirements, flexibility ratio and optimality ratio.

C. COMPUTATIONAL INTELLIGENCE PARADIGMS

QoS is the basic need of every end user and the objective of every network that must assure the QoS for the end user. To attain this target, the network is necessary to investigate the application requirements and set up a variety of network QoS mechanisms. In this survey, we study the appropriate level to QoS management. We see that the many protocols use famous simulation techniques. Although it seems to just a technical issue but developing a QoS specific computational technique will boost the research in this area.

IV. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Current WSNs are not only used for traditional low data rate applications but also for complex operations which require efficient reliable and timely collection of a large amount of data. Moreover, WSN consists of heterogeneous nodes. Increasing capacities of sensor nodes, a variety of the application fields and multi-model use of sensor require efficient QoS provisioning mechanism in WSNs. With these requirements in mind, we have focused on the perspective, challenges, needs, metrics, parameters and requirements of QoS protocols for WSNs. In this paper, we presented a comprehensive review of research challenges and the state of the art of QoS algorithms for WSNS and highlight the pros and cons and also the performance issues of each algorithm. The recent survey shows that researchers have focused their attention on the innovative use of CI techniques to address QoS management issue in WSNs. We have studied various CI in the survey and shown that each CI method solves a particular QoS management problem. We believe that this review paper will further promote and facilitate research in this direction. In the following, we mention some possible directions for future investigations.

- All the layers of TCP/IP communication protocol stack have some basic QoS parameters. In the selection of effective and poor efficient path for transmission many layers are involved such as network, data-link, and physical layers. To achieve this Cross-layer (X-layer) approach seems to be a better and more efficient solution. An interesting direction towards designing a cross-layer framework is still an open issue for future discussion.
- WSNs have many application fields and each application is composed of different types of sensor nodes and generating an even different type of traffics. In the WSNs terminology, it is called heterogeneous WSNs field. So to achieve the diverse QoS requirements it is needed to design the novel MAC protocol for channel distribution based on the traffic types.
- The discussed algorithms don't take the mobility issue which adversely affects the QoS of the WSNs. In sensor field, the sink node, sensor node and target node may be highly mobile. These mobile nodes have improved the performance of WSNs such as energy efficiency and coverage. To manage the mobility of nodes it requires an intelligent technique to be developed.
- Channel distribution/allocation is another open issue of interest. Multi channels routeing protocol provide high bandwidth, but it requires a more intelligent algorithm to assign channels to active nodes for transmission.
- To differentiate the services provided by the WSNs new protocols are required. The protocols satis-

fying the QoS requirements is an important design issue in WSNs.
- It is also needed to design the protocols which provide distributed control rather than the centralized control.
- The data redundancy issue is an important problem for WSNs. The QoS requirements is to reduce the data redundancy and delay. It is an open problem to develop such protocols.

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