QOS for WSN through Advance Neural Network

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Abstract- A wireless sensor network (WSN) is a computer wireless network composed of spatially distributed and autonomous tiny nodes smart dust sensors, motes -, which cooperatively monitor physical or environmental conditions. Nowadays these kinds of networks support a wide range of applications, such as target tracking, security, environmental control, habitat monitoring, source detection, source localization, vehicular and traffic monitoring, health monitoring, building and industrial monitoring, etc. Many of these applications have strong requirements for end-to-end delay and losses during data transmissions. In this work we have classified the main mechanisms that have been proposed to provide Quality of Service (QoS) in WSN at Medium Access Control (MAC) and network layers. Finally, taking into account some particularities of the studied MAC- and network-layer protocols, we have selected a real application scenario in order to show how to choose an appropriate approach for guaranteeing performance in a WSN deployed application.

Keywords- QoS, WSN, MAC, E2Edelay, PRD, Throughput

I. INTRODUCTION

Quality of service is an overused term with multiple meanings and perspectives from different research and technical communities [1]. QoS in WSNs can be viewed from two perspectives: application-specific and network. The former refers to QoS parameters specific to the application, such as sensor node measurement, deployment, and coverage and number of active sensor nodes. The latter refers to how the supporting communication network can meet application needs while efficiently using network resources such as bandwidth and power consumption.With the recent technological developments of the wireless networks and multifunctional sensors with processing and communication capabilities, wireless sensor networks (WSNs) have been used in an increasing number of applications. WSNs can provide a more accurate or reliable monitoring service for different classes of applications [2,3]. Quality of service can be an important mechanism to guarantee that the distinct requirements for different classes of applications are met [4].Traditional QoS mechanisms used in wired networks aren't adequate for WSNs because of constraints such as resource limitations and dynamic topology. One of the many challenges concerning wireless sensor networks (WSNs) is how to provide Quality of Service (QoS) parameter guarantees in real-time applications [5]. Therefore, middleware should provide new mechanisms to maintain QoS over an extended period and even adjust itself when the required QoS and the state of the application changes. Middleware should be designed based on trade-offs among performance metrics such as network capacity or throughput, data delivery delay, and energy consumption in order to provide QoS in Wireless Sensor Network.

a. QoS Concept

As defined in [6], Quality-of-Service is a set of service requirements to be met by the network while transporting a flow. "Here a flow is" a packet stream from source to a destination (unicast or multicast) with an associated Quality of Service (QoS) [6]. In other words, QoS is a measurable level of service delivered to network users, which can be characterized by packet loss probability, available bandwidth, end-to-end delay, etc. Such QoS can be provided by network service providers in terms of some agreement (Service Level Agreement, or SLA) between network users and service providers. For example, users can require that for some traffic flows, the network should choose a path with minimum 2M bandwidth.

b. QoS Metrics

For quality of service to be implemented, service requirements have to be expressed in some measurable QoS metrics. The well-known metrics include bandwidth, delay, jitter, cost, loss probability, etc. Different metrics may have different features. There are 3 types of metrics when talking about QoS: additive, multiplicative, and concave. These can be defined as follows:

Let $m(n_1, n_2)$ be a metric for link (n_1, n_2). For any path $P = (n_1, n_2, \cdots, n_i, n_j)$, metric m is: (Note here $n_1, n_2, n_3, \cdots, n_i, n_j$ represent network nodes)

additive, if $m(P) = m(n_1, n_2) + m(n_2, n_3) + \cdots + m(n_i, n_j)$

Examples are delay, jitter, cost and hop-count. For instance, the delay of a path is the sum of the delay of every hop.

multiplicative, if $m(P) = m(n_1, n_2) * m(n_2, n_3) * \cdots * m(n_i, n_j)$

Example is reliability, in which case $0 < m(n_i, n_j) < 1$.

concave, if $m(P) = \min\{m(n_1, n_2), m(n_2, n_3), \cdots, m(n_i, n_j)\}$

Example is bandwidth, which means that the bandwidth of a path is determined by the link with the minimum available bandwidth.

II. PROVIDING QoS IN WSNS

a. Directed diffusion

Directed Diffusion [7] is a data-centric and application aware paradigm since all data generated by sensor nodes is named by attribute-value pairs. Directed diffusion, unlike traditional end-to-end routing, tries to find routes from multiple sources to a single destination which allows redundant data aggregation. The objective of directed diffusion paradigm is to aggregate the different data coming from different sources by deleting redundancy. This particularity reduces the number of transmissions drastically, leading to two main consequences: firstly, the network saves energy and extends its time-life, and secondly, it has higher bandwidth in the links near to the sink node. This second factor could be decisive in order to provide QoS for real-time applications. Directed diffusion is based on a query-driven model. This means that the sink node requests data by means of broadcasting *interests.* Requests can be originated from humans or systems, and they are defined as pair-values, which describe a task to be done by the network. The interests are disseminated through the network. This dissemination sets up gradients to create data that will satisfy queries towards the requesting node. When the events begin to appear, they start to flow towards the originators of interests along multiple paths. This behavior provides reliability to data transmissions in the network. Other directed diffusion characteristic is the caching of data (generally attribute-value pair's interests). Caching can increase efficiency, robustness and scalability of coordination between sensor nodes, which is the essence of the directed diffusion paradigm.

b. SPIN

In [8] and [9] a family of adaptive protocols called Sensor Protocols for Information via Negotiation (SPIN) is proposed. These protocols do not implement any concrete QoS mechanism; they are based on an interesting data negotiation mechanism. SPIN uses this for eliminating redundant data by means of meta-data exchange. Nodes running SPIN assign a high-level name (called meta-data) to describe the data that they have collected and they perform meta-data negotiations before any actual information is transmitted. The main goal of this mechanism is similar to the typical aggregation systems. However, this mechanism has an advantage over other systems: it avoids redundant data transmissions for later processing. This way, the network increases its life time and the available bandwidth. Additionally, nodes are free from the processing load that the data aggregation implies. Of course, the format of the exchanged meta-data has to be carefully designed in order not to make the nodes transmit very voluminous information (which again would cause waste of energetic resources). A totally general format for this metadata would probably have this problem. That is why the authors that propose SPIN do not specify a format for the meta-data, but instead they state that this format should be application-dependent in order to choose a fine-tuned set of criteria that minimizes the meta-data volume of information while serving the application functionality.

c. TEEN and APTEEN

TEEN and APTEEN, proposed in [10] and [11], have been defined for time-critical applications. These protocols are designed to work even in the event of abrupt changes in the attribute values that are being measured by the sensors. APTEEN (Adaptive TEEN) is a modification of TEEN that additionally considers the case of periodic transmissions of measurements towards the sink node. This protocol implements a very complex query system. Using this system it is possible to achieve three types of queries (historical, one-time, and persistent). All of these queries are posed by an external user through the sink node. The historical and persistent queries do not have QoS requirements. However, one-time queries have critical time constraints. In this case, for instance, the end user may want to be aware of the geographical position of a target with minimum delay. In order to achieve minimum delay, the system executes a special time slots assignment to each node using a TDMA schedule. Furthermore, APTEEN performs an important task of data aggregation, which leads to having free bandwidth and energy saving.

d. SAR

Sequential Assignment Routing (SAR), proposed in [12], is one of the first protocols for WSN that has considered QoS issues for making routing decisions. SAR makes routing decisions based on three factors: energy resources, QoS planned for each path, and the type of traffic to which the packet belongs to (types of traffic are implemented by means of a priority mechanism). SAR uses two systems for resolving reliability problems which consist in a multi-path approach and a localized path restoration (this path restoration is done by means of communications between neighbour nodes). The multipath tree is defined avoiding nodes with low energy or QoS guarantees; taking into account that the tree root is located in the source node and the end is the sink nodes set. In conclusion, SAR will create a multi-path table whose main objective is to have energy efficiency and fault tolerance. Although this ensures fault tolerance and easy recovery, the protocol suffers from certain overhead when the tables and the node states must be maintained (refreshed). This problem is especially significant when there is a huge number of nodes.

e. SPEED

SPEED [13] is another QoS routing protocol for WSN that provides light real-time end-to-end guarantees. The QoS mechanism employed by SPEED is based on estimation procedures. The application in a node estimates the required speed for a certain delay, taking into account its distance to the sink node. The network layer will admit the packet depending on the required speed. Moreover, SPEED will be able to recover if the network becomes congested. The routing module in SPEED is called Stateless Nondeterministic Geographic Forwarding. (SNGF). This module implements a distributed database where a node can be selected in order to reach the speed requirement.

f. MMSPEED

MMSPEED (*Multi-Path and Multi-SPEED Routing Protocol*) [13] is a novel packet delivery mechanism for QoS provisioning. Its main goal is to provide QoS differentiation in two quality domains, *timeliness* and *reliability*: Traffic flows will be cursed with combination of service options based on reliability and timeliness requirements. The method used by MMSPEED to obtain reliability is the typical multi-path routing, with a number of paths that depends on the required degree of reliability for the traffic flows. On the other hand, the method used by MMSPEED to obtain timeliness is a dynamic system which guarantees the packet delivery speed. MMSPEED employs localized geographic forwarding by using only local node neighbor information. The local decisions imply an inaccuracy problem, which is resolved by dynamic compensation. Thus, traffic flows requirements can be fulfilled with a high probability. With this mechanism the intermediate nodes have ability to increase the transmission packet speed to higher levels if they estimate that with the current associated speed the packet cannot fulfill its delay deadline, but it could be met at higher speeds. In order to offer the necessary functionality to the QoS mechanisms implemented by MMSPEED, a MAC protocol with a prioritization mechanism should be established. In this sense, the MMSPEED specification recommends the use of 802.11e (with several add-ons) at the MAC layer with its inherent prioritization mechanism based on the Differentiated Inter-Frame Spacing (DIFS). Each speed value is mapped onto a MAC layer priority class. MMSPEED protocol solves many QoS issues related to real time traffic in WSN. However, many other aspects, such as network layer aggregation or handling the energydelay trade-off, still need to be dealt with in deep in order to have good performance in a deployed WSN.

g. Energy-aware QoS Routing

In [15] the authors propose a QoS-aware protocol for realtime traffic generated by a WSN consisting of image sensors. This protocol implements a priority system that divides the traffic flows in two classes: *best effort* and *real-time*. All nodes use two queues, one for each traffic class. This way, different kinds of services can beprovided to these types of traffic. Also, the protocol implements a routing mechanism based on multi-path which uses an extended version of the Dijkstra's algorithm. This makes it possible to provide certain reliability in the data transmissions. The source node chooses a route in order to achieve the end-to-end requirements and then forwards the packet to the next hop neighbor in the route. Each intermediate node classifies the received packet into real-time or best-effort. The scheduling algorithm is such that the best effort traffic cannot reduce the resources for the real-time traffic. The main disadvantage of this protocol is that it supports only one real-time traffic priority. This characteristic can be appropriate for a network with a single real-time application, but in a network with multiple applications it would be interesting to have several types of real-time traffic with different priorities.

III. QoS CHALLENGES IN SENSOR NETWORKS

Different from IP network, Sensor network naturally supports multiple service types, thus provides different QoS. The service types range from CBR (Constant Bit Rate) which guarantees bandwidth, delay and delay jitter, to UBR (Unspecified Bit Rate) which virtually provides no guarantees (just like today's "best-effort" IP network). While sensor networks inherit most of the QoS issues from the general wireless networks, their characteristics pose unique challenges. The following is an outline of design considerations for handling QoS traffic in wireless sensor networks.

Bandwidth limitation: A typical issue for general wireless networks is securing the bandwidth needed for achieving the required QoS. Bandwidth limitation is going to be a more pressing issue for wireless sensor networks. Traffic in sensor networks can be burst with a mixture of real-time and non-real-time traffic. Dedicating available bandwidth solely to QoS traffic will not be acceptable. A trade-off in image/video quality may be necessary to accommodate non-real-time traffic. In addition, simultaneously using multiple independent routes will be sometime needed to split the traffic and allow for meeting the QoS requirements. Setting up independent routes for the same flow can be very complex and challenging in sensor networks due energy constraints, limited computational resources and potential increase in collisions among the transmission of sensors.

Removal of redundancy: Sensor networks are characterized with high redundancy in the generated data. For unconstrained traffic, elimination of redundant data messages is somewhat easy since simple aggregation functions would suffice. However, conducting data aggregation for QoS traffic is much more complex. Comparison of images and video streams is not computationally trivial and can consume significant energy resources. A combination of system and sensor level rules would be necessary to make aggregation of QoS data computationally feasible. For example, data aggregation of imaging data can be selectively performed for traffic generated by sensors pointing to same direction since the images may be very similar. Another factor of consideration is the amount of QoS traffic at a particular moment. For low traffic it may be more efficient to cease data aggregation since the overhead would become dominant. Despite the complexity of data aggregation of imaging and video data, it can be very rewarding from a network performance point-of-view given the size of the data and the frequency of the transmission.

Energy and delay trade-off: Since the transmission power of radio is proportional to the distance squared or even higher order in noisy environments or in the nonflat terrain, the use of multi-hop routing is almost a standard in wireless sensor networks. Although the increase in the number of hops dramatically reduces the energy consumed for data collection, the accumulative packet delay magnifies. Since packet queuing delay dominates its propagation delay, the increase in the number of hops can, not only slow down packet delivery but also complicate the analysis and the handling of delay-constrained traffic. Therefore, it is expected that QoS routing of sensor data would have to sacrifice energy efficiency to meet delivery requirements. In addition, redundant routing of data may be unavoidable to cope with the typical high error rate in wireless communication, further complicating the trade-off between energy consumption and delay of packet delivery.

Buffer size limitation: Sensor nodes are usually constrained in processing and storage capabilities. Multi-hop routing relies on intermediate relaying nodes for storing incoming packets for forwarding to the next hop. While a small buffer size can conceivably suffice, buffering of multiple packets has some advantages in wireless sensor networks. First, the transition of the radio circuitry between transmission and reception modes consumes considerable energy and thus it is advantageous to receive many packets prior to forwarding them. In addition, data aggregation and fusion involves multiple packets. Multihop routing of QoS data would typically require long sessions and buffering of even larger data, especially when the delay jitter is of interest. The buffer size limitation will increase the delay variation that packets incur while traveling on different routes and even on the same route. Such an issue will complicate medium access scheduling and make it difficult to meet QoS requirements.

Support of multiple traffic types: Inclusion of heterogeneous set of sensors raises multiple technical issues related to data routing. For instance, some applications might require a diverse mixture of sensors for monitoring temperature, pressure and humidity of the surrounding environment, detecting motion via acoustic signatures and capturing the image or video tracking of moving objects. These special sensors are either deployed independently or the functionality can be included on the normal sensors to be used on demand. Reading generated from these sensors can be at different rates, subject to diverse quality of service constraints and following multiple data delivery models, as explained earlier. Therefore, such a heterogeneous environment makes data routing more challenging.

IV. BACKGROUND

In [16],the emerging field of wireless sensor networks (WSNs) combines sensing, computation and communication into a single tiny device. The power of wireless sensor networks lies in the ability to deploy large numbers of tiny nodes that assemble and configure themselves. Usage scenarios for these devices range from real-time tracking, monitoring of environmental conditions, ubiquitous computing environments, in situ monitoring of the health of structures or equipment. The up-coming networks are expected to support a wide range of communication-intensive, real-time multimedia applications. The requirement for timely delivery of data raises new challenges for the next generation networks. One of the key issues is the Quality-of-Service (QoS) routing. It selectsnetwork routes with sufficient resources for the requested QoSparameters. Node routing protocols have been specifically designed for WSNs in which energy conservation is an essential design issue. Rumour Routing (RR) is a hybrid protocol which combines both proactive and reactive routing methods, which balances event, query flooding and adapted to the case of few data and many queries. It is proposed to develop a QoS based Relative Coordinate Rumour Routing protocol based on a straight line random walk approach. The main objective is to evaluate the performances of the proposed protocol under different situations and considering different factors such as network size or the impact of the positions of the Beacon nodes. The performances are evaluated through network simulator2 (NS2).The simulation results indicate thesuperiority of proposed scheme compared with RumourRouting, in terms of performance indices, provide better path quality and higher data delivery ratio.

In [17],The Wireless sensor network (WSN) deployment areas in real time environment are often inaccessible and unreliable communication resulting in degradation of network performance. The critical issues in any WSN are QoS and energy. Post deployment, it may not always be feasible to replace the batteries in a WSN. Long hops of transmission maintaining the QoS with more energy consumption results in reduction of network lifetime. This paper concentrates on adjustment of power, range and bit rates to attain adaptive topology control (ATC) at physical layer to maintain optimum QoS. The simulation has been carried out using Omnet++ 4.6 along with MIXIM 2.3 framework. A comparison of a conventional WSN or non-ATC and ATC based WSN has been made involving range, throughput and packet delivery ratio and an improvement of 29% has been observed in ATC.

In [18], Connecting wireless sensor networks (WSNs) to remote servers or clouds through the Internet of Things inspires the formation of a highly complex system. This has significant potential to encourage WSNsoftwarization. Such a network enables interaction between the physical and virtual sensor network, allowing for flexibility within the physical system to adapt with the dynamics of the service requirements. An architecture of a test environment with adaptive quality of service (AQoS) has been presented. The concept provides an avenue for a flexible system that is capable of reacting to dynamic changes of process demands. Physical network performance can be predicted by analyzing the historical data in the background on a networksimulator or virtual network. This in turn allows for estimation of the necessary adjustments needed to improve the network performance without disturbing the physical system. This paper reports the experimentation and applicability of user drivenA-QoS models on the system. Early stages of testing the organization, taking into account the system behavior and subsequent reaction to necessary adjustment of the WSN operational configuration, has shown encouraging results.

In [19], In many applications of Industrial Sensor Networks, stringent reliability and maximum delay constraints paired with priority demands on a sensor-basis are present. These QoS requirements pose tough challenges for Industrial Wireless Sensor Networks that are deployed to an ever larger extent due to their flexibility and extendibility. In this paper, they introduce an integrated cross-layer framework, SchedEx-GA, spanning MAC layer and network layer. SchedEx-GA attempts to identify a network configuration that fulfills all application-specific process requirements over a topology including the sensor publish rates, maximum acceptable delay, service differentiation, and event transport reliabilities. The network configuration comprises the decision for routing, as well as scheduling. For many of the evaluated topologies it is not possible to find a valid configuration due to the physical conditions of the environment. They therefore introduce a converging algorithm on top of the framework which configures a given topology by additional sink positioning in order to build a backbone with the gateway that guarantees the application specific constraints. The results show that, in order to guarantee a high end-to-end reliability of 99:999% for all flows in a network containing emergency, control loop, and monitoring traffic, a backbone with multiple sinks is often required for the tested topologies. Additional features, such as multi-channel utilization and aggregation, though, can substantially reduce the demand for required sinks. In its present version, the framework is used for centralized control, but with the potential to be extended for de-centralized control in future work.

In [20], the vision of wireless multimedia sensor networks (WMSNs) is to provide real-time multimedia applications using wireless sensors deployed for long-term usage.Quality of service assurances for both best effort data andreal-time multimedia applications introduced new challenges in prioritizing multipath routing protocols in WMSNs. Multipath routing approaches with multiple constraints have received considerable research interest. In this paper, a comprehensive survey of both best effort data and real-time multipath routing protocols for WMSNs is presented. Results of a preliminary investigation into design issues affecting the development of strategic multipath routing protocols that support multimedia data in WMSNs are also presented and discussed from the network application perspective.

In [21], the versatility and low energy consumption of Wireless Sensor Networks (WSN), makes this technology a potential tool for the development of large-scale networks, where access to communication services and energy consumption present some limitation. Because of this, it becomes a potential solution for development of post-seismic alarm networks. The registration of the maximum acceleration peaks, that could be experiment by building structures after an earthquake, could be used to help to identify potentially affected areas after the occurrence of a seismic event. However, the number of message that could be generated in the network could affect the effective delivery of reported data. Because message congestion could become a critical factor that affect the successful delivery of data over the network. In this paper, is being shown a performanceevaluation of a post-seismic assessment solution through different scenarios where load balancing Load-Aware On-Demand Routing (LAOR) and Flooding protocols were analyzed, as well as the use of a mechanism to desynchronize the send of messages in the network, based on the Backoff Algorithm of IEEE 802.15.4 Standard. An additional Backofftime called WT is also proposed for network desynchronization to achieve some improvement in the network QoS. The simulation results show that our proposal significantly improve performance on both protocols. The different scenarios that were evaluated considered the possibility of the collapse of some buildings after a strong or moderate magnitude event and the effect that this fact can introduce in the message traffic through the network in a seismic event conditions.

In [22], Wireless sensor network is a large collection of sensor nodes deployed in a particular area. These sensor nodes sense the area under consideration, and send signals to notify the sink node about changes in the area. Congestion may occur in the network, as signals from various nodes may be sent simultaneously. Each sensor node in the network consists of a buffer which may be used to get better performance in the network. The buffer size plays a very important role on the performance of the network. For an optimum buffer size, the throughput of the network increases considerably, whereas the delay in network can be reduced. This paper discusses various buffer management and buffer size related schemes proposed by various authors. Here they also present the various simulation results from which, they can conclude that the buffer size is very important parameter in the performance of network.

In [23],Wireless sensor networks (WSNs) have gained much attention in today's research domain for supporting a wide variety of applications including the multimedia applications. Multimedia applications that are regarded as the quality-of-service (QoS)-aware, delay sensitive, and bandwidth hungry applications require enough energy and communication resources. WSNs being the energy-scarce network have now been designed in such a way that they can support these delay-sensitive and time-critical applications. In this paper, they propose an energy efficient routing protocol for heterogeneous WSNs to support the delay sensitive, bandwidth hungry, time-critical, and QoS-aware applications. The proposed QoS-aware and heterogeneously clustered routing (QHCR) protocol not only conserves the energy in the network, but also provides the dedicated paths for the real-time and delay sensitive applications. The inclusion of different energy-levels for the heterogeneous WSNs also provides the stability in the networks while minimizing the delay for the delay-sensitive applications. Extensive simulations have been performed to validate the effectiveness of our proposed scheme. Our proposed routing scheme outperforms other state-of-the-art schemes in terms of the delay performances.

V. OPEN RESEARCH ISSUES

As we know, QoS-enabled traditional networks attempt to ensure: That applications/users have their QoS requirements satisfied, while ensuring an efficient resource usage, i.e., and efficient bandwidth utilization. That the most important traffic still has its QoS requirements satisfied during network overload. In the context of WSNs, efficient resource usage not only means efficient bandwidth utilization, but also a minimal usage of energy. Thus, QoS support in WSNs should also include QoS control mechanisms besides QoS assurance mechanisms employed in traditional networks, which can eliminate unnecessary energy consumption in data delivery. Further, besides during network overload, the most important traffic should still have its QoS requirements satisfied in the presence of different types of network dynamics, which may arise from node failure, wireless link failure, node mobility, and node state transition. We have listed the main technical challenges in Section IV. Based on these challenges and our goals, the following are identified as open research issues in QoS support in WSNs.

1) Simpler QoS models*:* Diffserv and Interserv models may be not applicable in WSNs due to their complexity. Novel and simple QoS models are required to identify the architecture for QoS support in WSNs. Cross layer instead of traditional layered design may be helpful to work out a simpler model.

2) QoS-aware data dissemination protocols*:* It is very interesting to analyze how these protocols such as directed diffusion support QoS-constrained traffic while minimizing energy consumption. Do these protocols support priority? Can the network send high-priority traffic even with overloaded traffic situation or under a highly dynamic network?

3) Services: What kind of non-end-to-end services can WSNs provide? Are traditional best effort, guaranteed, and differentiated services still feasible in this new paradigm?

4) QoS support based on collective QoS parameters: It is very interesting to explore the support mechanisms for three classes of data delivery models using collective QoS parameters. Further, how do the mechanisms differ from those in traditional networks?

5) Traditional end-to-end energy-aware QoS support: Although these are not of main concern in WSNs, they may be applied in some scenarios. Also, it is very interesting to explore the limit on QoS assurance in an extremely resource constrained network.

6) Trade-offs*:* Data redundancy in WSNs can be intrinsically exploited to improve information reliability. However, it spends too much energy to transmit these redundant data. If we introduce data fusion, it can reduce data redundancy in order to save energy, but it also introduces much delay into the network. What is an optimum trade-off among them? This optimum trade-off may be achieved analytically or by network simulations.

7) Adaptive QoS assurance algorithms: It is desirable to maintain QoS throughout the network life instead of having a gradual decay of quality as time progresses. This prevents gaps in data sets received by the sink. These gaps, that directly affect QoS, are caused by network dynamics. As a result, some adaptive QoS algorithms may be required to defend against network dynamics.

8) Service differentiation: What is the criteria of differentiation? Should it be based on traffic types, data delivery models, sensor types, application types, or the content of packets? Considering the memory and processing capability limitations, we cannot afford to maintain too many flow states in a node. Thus, it is desirable to control network resource allocation to a few differentiated traffic classes such that a desired maximum resource utilization is obtained.

9) QoS support via a middleware layer:If QoS requirements from an application are not feasible in the network, the middleware may negotiate a new quality of service with both the application and the network. Such a middleware layer, which may be used to translate and control QoS between the applications and the networks, is of great interest.

10) QoS control mechanisms:Sensors may send excessive data sometimes and thereby waste precious energy while they may also send inadequate data at other times so that the quality of the application cannot be met. Some novel centralized or distributed QoS control algorithms are desired.

11) The integration of QoS support: The mechanisms of QoS support in WSNs may be very different from that in traditional networks. However, since the requests to WSNs can be from a user/application through a traditional network such as the Internet, further research is necessary for handling the differences between them and maintain the QoS service seamless to the application running over both networks.

VI. CONCLUSION

Few efforts have been made in the research field of QoS support in WSNs so far. In this survey paper, we analyzed the QoS requirements imposed by the main applications of WSNs, and we claim that the end-to-end QoS concept used in traditional networks may not be sufficient in WSNs. Some non-end-to-end collective QoS parameters are envisioned dueb to this significant change. Further, we list many challenges posed by the unique characteristics of WSNs and report on the state of the art in terms of a few current research efforts in this field. Finally, we are convinced that the QoS support in WSNs should also include QoS control besides QoS assurance mechanisms, and some exciting open issues are identified in order to stimulate more creative research in the future.

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