QoS-Based Routing Protocols for Wireless Sensor Networks: A Survey

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Abstract: According to multiconstrained characteristics of Wireless sensor networks (WSNs), we need to forward collected data in quality of service (QoS) based. Many applications of WSN, such as target tracking, forest fire detection and biomedical, have diverse data traffic such as normal, reliability-sensitive, delay-sensitive and critical packets with different QoS requirements. A typical example of such a scenario is patient monitoring in a hospital room, where different health parameters are to be captured and forwarded to health care servers accessible by the medical staff. This survey investigates Qos-based routing protocols for wireless sensor networks. The main objectives of QoS-based routing protocols are to provide reliable and real-time communication and to ensure prolonging network lifetime. The goals are to improve delay, provide reliability, reduce overhead and maximize network lifetime. Issues, objectives, performances, advantages and disadvantages of these protocols are investigated and summarized. of service, routing protocol, Energy efficiency, Critical mission.

Key words: Wireless sensor networks · Quality

INTRODUCTION

Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources and they are inexpensive compared to traditional sensors [1,2]. These sensor nodes can sense, measure and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user. Many applications of wireless sensor networks, such as vehicular and biomedical, have diverse data traffic with different QoS requirements. We consider a general scenario typical for many of the targeted WSN applications, where sensors collect different kinds of data and transmit them toward fixed sinks via other sensors in a multi-hop, ad hoc paradigm. A typical example of such a scenario is patient monitoring in a hospital room, where different health parameters are to be captured and forwarded to health care servers accessible by the medical staff. Traffic is diverse and may have different QoS requirements, depending on the monitored parameter and its value, the patient health

situation, the patient context, e.g., regular monitoring versus monitoring in operating room, etc. Three different classes of QoS requirements are used in the investigated protocols: 1) energy efficiency (including both residual energy and the required transmission power), 2) reliability and 3) latency.

Wireless sensor networks can be used for many mission-critical applications such as target tracking in battlefields and emergency response. In these applications, reliable and timely delivery of sensory data plays a crucial role for the success of the mission. Specifically, the abovementioned sensor network applications share the following characteristics:

Diverse Real-Time Requirements: Some sensory data reflects the physical status of dynamically changing environment such as positions of moving targets and temperatures of forest areas. Such sensory data is valid only for a limited time duration and, hence, needs to be delivered within a time deadline for real-time applications. More importantly, different sensory data has different deadlines depending on the dynamics of the sensed environment. For example, location information of a fast moving target has shorter deadline than that of a slow moving target.

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Diverse Reliability Requirements: Depending on its contents, sensory data may have different reliability requirements. For example, in a forest monitoring application, the temperature information in the normal temperature range can be delivered to the control center tolerating a certain percentage of loss. On the other hand, the sensor data reflecting a high temperature should be delivered to the control center with a very high probability since it can be a sign of fire.

Mixture of Periodic and Aperiodic Data: Some sensory data are created aperiodically by detection of critical events at unpredictable times. In addition, there are other types of sensory data created periodically for continuous real-time monitoring of environmental status. QoS provisioning for the above diverse flows is a challenging problem due to the following characteristics of sensor networks:

- Dynamic topology changes due to node mobility, failure and addition;
- Large scale with thousands of densely placed nodes; and
- Less reliable nature due to noisy wireless links

The rest of the paper is organized as follows. In section II, detailed operational descriptions, advantages, disadvantages and limitations of the QoS-based routing protocols will be discussed. Section III concludes the paper.

QoS-based Routing Protocols: In recent years, QoS routing in location-aware wireless sensor networks has received much research interests due to its inherent characteristics of (i) being scalable to large networks, (ii) making routing decisions based on local neighborhood
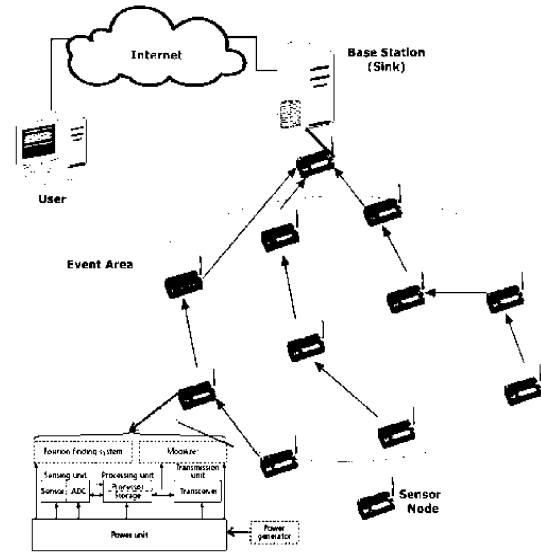

Fig. 1: Wireless sensor networks architecture

information and (iii) being very adaptive under dynamic changes and mobility as only a node's neighborhood is affected. Most of the applications developed for wireless sensor networks demand the QoS aware routing protocol in order to deliver the high critical data more reliably with minimum number of message exchanges. This will lead to achieve significant energy conservation and low delivery latency under congested network condition. Figure 2 shows the classification of routing protocols for WSNs. We will investigate the QoS-based routing protocols.

RAP (Real-time Communication Architecture): Large-scale wireless sensor networks represent a new generation of real-time embedded systems with Significantly different communication constraints from traditional networked systems.
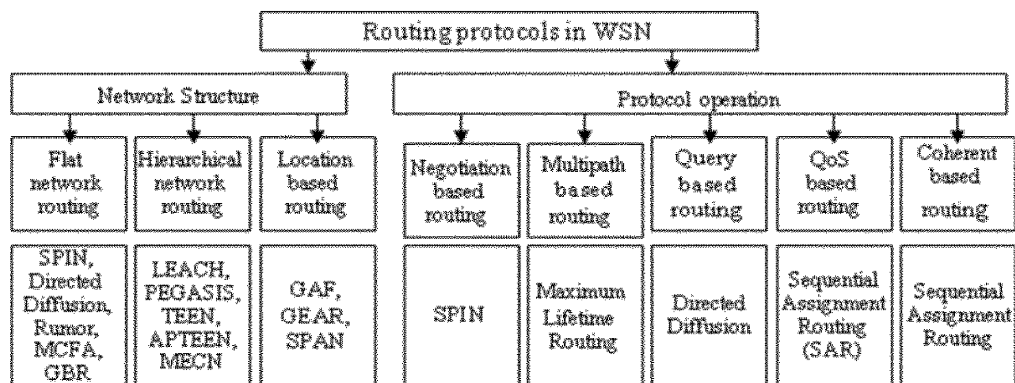

Fig. 2: Routing protocols in WSNs (Classification)

RAP[3], addresses a new real-time communication architecture for large-scale sensor networks. RAP provides convenient, high-level query and event services for distributed micro-sensing applications. Novel location-addressed communication models are supported by a scalable and light-weight network stack. RAP presents and evaluates a new packet scheduling policy called velocity monotonic scheduling that inherently accounts for both time and distance constraints. this policy is particularly suitable for communication scheduling in sensor networks in which a large number of wireless devices are seamlessly integrated into a physical space to perform real-time monitoring and control.

The goal of RAP includes the following:

- Provide general service APIs that is suitable for distributed micro-sensing and control in sensor networks
- Maximize the number of packets meeting their end-to-end deadlines
- Scale well with large number of nodes and hops
- Introduce minimum communication and processing overhead.

The architecture of RAP is shown in figure 3. Sensing and control applications interact with RAP through a set of Query/Event Service APIs. A Query/Event Service layer submits the query or event registration to an area. The Query/Event Service at the sensors in that area then (periodically or aperiodically) sends query results back to the base station. If an event is registered, the query is started only if the registered event happens. The sensor-base communication is supported by a network stack including a transport-layer Location-Addressed Protocol (LAP), a Geographic Forwarding (GF) routing protocol, a Velocity Monotonic (packet) Scheduling (VMS) layer and a prioritized MAC. This network stack embodies a set of efficient and localized algorithms to reduce the end-to-end deadline miss ratio of sensor-base communication. The coordination service is responsible of dynamic group management and data aggregation among sensors.

SAR (Sequential Assignment Routing): The SAR (Sequential Assignment Routing [4]is the first routing protocol for sensor network that includes a notion of QoS. Assuming multiple paths to the sink node, each sensor uses a SAR algorithm for path selection. It takes into account the energy and QoS factors on each path and the priority level of a packet. For each packet routed through
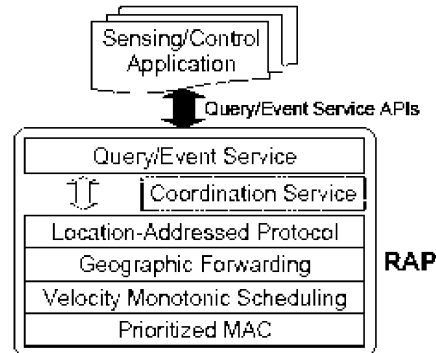

Fig. 3: RAP architecture

the network, a weighted metric is computed as the product of the additive metric and a weight coefficient associated with the priority level of that packet for purposes of performance evaluation. The objective of the SAR algorithm is to minimize the average weighted metric throughout the lifetime of the network.

Speed: SPEED [5], presents a real-time communication protocol for sensor networks. The protocol provides three types of real-time communication services namely, real-time uncast, real-time area-multicast and real-time area-anycast. SPEED is specifically tailored to be a stateless, localized algorithm with minimal control overhead. End-to-end soft real-time communication is achieved by maintaining a desired delivery speed across the sensor network through a novel combination of feedback control and non-deterministic geographic forwarding. SPEED is a highly efficient and scalable protocol for sensor networks where the resources of each node are scarce. SPEED maintains a desired delivery speed across sensor networks by both diverting traffic at the networking layer and locally regulating packets sent to the MAC layer. It consists of the following components:

- An API
- A neighbor beacon exchange scheme
- A delay estimation scheme
- The Stateless Non-deterministic Geographic Forwarding algorithm (SNGF)
- A Neighborhood Feedback Loop (NFL)
- Backpressure Rerouting
- Last mile processing

As shown in Figure 4, SNGF is the routing module responsible for choosing the next hop candidate that can support the desired delivery speed. NFL and Backpressure Rerouting are two modules to reduce or
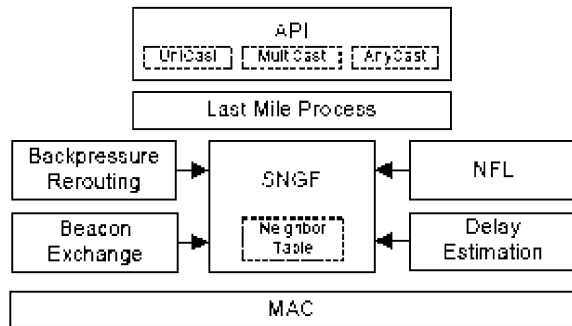
Fig. 4: Speed Architecture

divert traffic when congestion occurs, so that SNGF has available candidates to choose from. The last mile process is provided to support the three communication semantics mentioned before. Delay estimation is the mechanism by which a node determines whether or not congestion has occurred. And beacon exchange provides geographic location of the neighbors so that SNGF can do geographic based routing. SPEED attempts to route packets through routes that ensure a given fixed speed and uses Exponential Weighted Moving Average for link latency estimation. The aim of this protocol is basically to reduce delay, but it probabilistically chooses the node among the ones supposed to fulfill the required speed, which is energy efficient and balances the network load. However, SPEED does not consider reliability.

MMSPEED (Multi-Path and Multi-SPEED Routing Protocol): A novel packet delivery mechanism called Multi-Path and Multi-SPEED Routing Protocol (MMSPEED) [6] is introduced for probabilistic QoS guarantee in wireless sensor networks. The QoS provisioning is performed in two quality domains, namely, timeliness and reliability. Multiple QoS levels are provided in the timeliness domain by guaranteeing multiple packet delivery speed options. In the reliability domain, various reliability requirements are supported by probabilistic multipath forwarding. These mechanisms for QoS provisioning are realized in a localized way without global network information by employing localized geographic packet forwarding augmented with dynamic compensation, which compensates for local decision inaccuracies as a packet travels towards its destination. This way, MMSPEED can guarantee end-to-end requirements in a localized way, which is desirable for scalability and adaptability to large scale dynamic sensor networks. The goal of this protocol is to provide QoS differentiation in two quality domains, namely, timeliness and reliability, so that packets can choose the most proper

combination of service options depending on their timeliness and reliability requirements. The power consumption problem is beyond the scope of this paper since we target short-living sensor network applications whose mission duration lasts only for few hours or one day at most and, hence, QoS support for the mission duration is more important than prolonging the network lifetime. For the service differentiation in the timeliness domain, the proposed mechanism provides multiple network-wide speed options. For the service differentiation in the reliability domain, MMSpeed exploits the inherent redundancy of dense sensor networks by realizing probabilistic multipath forwarding depending on packet's reliability requirement. Another important property of MMSPEED is end-to-end QoS provisioning with local decisions at each intermediate node without end-to-end path discovery and maintenance. This property is important for scalability to large sensor networks, self-adaptability to network dynamics and appropriateness to both aperiodic and periodic traffic flows. For this, MMSPEED realizes the above QoS differentiation based on localized geographic forwarding using only immediate neighbor information. One challenge is to ensure that localized forwarding decisions result in end-to-end QoS provisioning in global sense. To handle this problem, MMSPEED proposes the notion of dynamic compensation, which compensates for inaccuracy of local decisions in a global sense as a packet progresses towards its destination. As a result, packets can meet their end-to-end requirements with a high probability even if packet delivery decisions are made locally. MMSPEED attempts to improve SPEED and defines multispeed routing, where several routing layers-ach ensuring a given speed-are used. Packets are associated with appropriate layers according to their required speed and reliability is ensured through probabilistic multipath toward a single sink, which may result in congestion at nodes near the sink. However MMSPEED does not consider energy parameters in data forwarding.

RPAR (Real-time Power-Aware Routing): Many wireless sensor network applications must resolve the inherent conflict between energy efficient communication and the need to achieve desired quality of service such as end-to-end communication delay. To address this challenge, the Real-time Power-Aware Routing (RPAR) [7] protocol is proposed, which achieves application-specified communication delays at low energy cost by dynamically adapting transmission power and routing decisions. RPAR features a power-aware forwarding policy and an
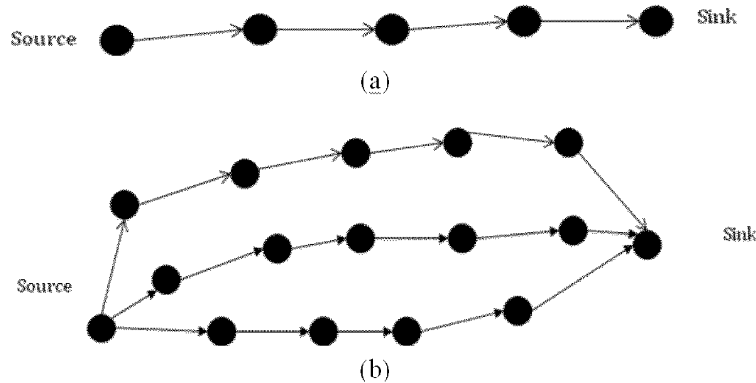
Fig. 5: (a) Single path data forwarding, (b) Multipath data forwarding

efficient neighborhood manager that are optimized for resource-constrained wireless sensors. Moreover, RPAR addresses important practical issues in wireless sensor networks, including lossy links, scalability and severe memory and bandwidth constraints.

RPAR Has Four Components: a dynamic velocity assignment policy, a delay estimator, a forwarding policy and a neighborhood manager. RPAR uses the velocity assignment policy to map a packet's deadline to a required velocity. The delay estimator evaluates the one-hop delay of each forwarding choice (N, p) in the neighbor table, i.e. the time it takes a node to deliver a packet to neighbor N at power level p. Based on the velocity requirement and the information provided by the delay estimator, RPAR forwards the packet using the most energy efficient forwarding choice in its neighborhood table that meets the required velocity. When the forwarding policy cannot find a forwarding choice that meets the required velocity in the neighbor table, the neighborhood manager attempts to find a new forwarding choice that meets the required velocity through power adaptation and neighbor discovery.

Rein Form (Reliable Information Forwarding Using Multiple Paths): ReInForm [7], uses the concept of dynamic packet state in context of sensor networks to control the number of paths required for the desired reliability using only local knowledge of channel error rates and does not require any prior computation or maintenance of these multiple paths. ReInForM leads to load balancing as well. Figure 5 shows the single path (a) and multi path (b) data forwarding schemes. Reinform routing protocol uses multipath data forwarding scheme for increasing reliability.

On generating a packet the source node determines the importance of the information it contains and decides the desired reliability r_s for it. It also knows the local channel error e_s and its hop distance from sink h_s. Using these values, the source computes the number of paths (or equivalently, the number of copies of the packet to be sent) P Prequired for delivering the packet at desired reliability to the sink as:

$$P(r_s, e_s, h_s) = \frac{\log(1 - r_s)}{\log(1 - (1 - e_s)h_g)}$$

Eres-QoS: Energy Reservation based QoS Aware Routing Protocol: The ERes-QoS [8]ensures end-to-end performance guarantee for high critical data on hop-by-hop basis in two domains: timeliness and reliability. An angle based router set is constructed at each node, to achieve on-time reachability of the data. For QoS provisioning in a reliability domain, we use local decision approach at each intermediate node, which exploits Multipath, Energy Reservation and hop-by-hop unicasting with acknowledgement, without end-to-end path discovery and maintenance. The Proposed protocol provides a differentiated routing service by assigning priorities to data packets according to their criticality. This is done by reserving the required energy to relay the traffic at the routers along the dynamically explored path and by employing packet classifier and multi-level queue priority scheduling modules at each intermediate node. As a result, the ERes-QoS achieves high data delivery ratio that meets both timeliness and reliability requirement. Simulation results demonstrate that, the ERes-QoS routing protocol provides significant improvements in data delivery latency, path establishment latency and data delivery ratio. The author's goal is to provide end-to-end QoS provisioning in reliability domain with local decisions
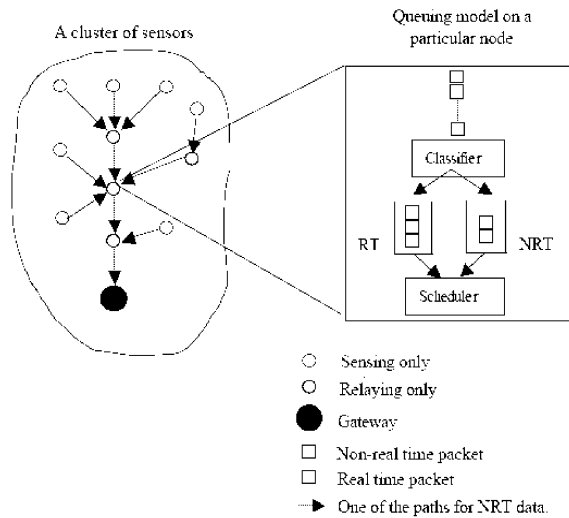
Fig. 5: Queuing model in cluster-based sensor network

at each intermediate node without end to-end path discovery and maintenance. To achieve this, the proposed protocol assigns appropriate priority levels to the sensed event depending on the information content. At each intermediate node, Packet classifier and Multi level queue scheduler module are used to discriminate and provide the service to the packets according to their priority, instead of using conventional first-in-first-out packet forwarding scheme.

DARA: DARA [9]considers reliability, delay and residual energy in the routing metric and defines two kinds of packets: critical and noncritical packets. The same weighted metric is used for both types of packets, where the only difference is that a set of candidates reached with a higher transmission power is considered to route critical packets. For delay estimation, the authors use queuing theory and suggest a method that, in practice, needs huge amount of sample storages.

In [10], the authors introduced an energy-aware QoS routing protocol for wireless sensor networks. Transmission of video and imaging data requires both energy and QoS aware routing in order to ensure efficient usage of the sensors and effective access to the gathered measurements. The protocol finds a least-cost, delay-constrained path for real-time data in terms of link cost that captures nodes' energy reserve, transmission energy, error rate and other communication parameters. Moreover, the throughput for non-real-time data is maximized by adjusting the service rate for both real-time and non-real-time data at the sensor nodes.

The protocol finds QoS paths for real-time data with certain end-to-end delay requirements. Moreover, the selected queuing model for the protocol allows the throughput for normal data not to diminish by employing a network wide r-value, which guarantees certain service rate for real-time and nonreal-time data on each link.

LOCALMOR: A new localized quality of service routing protocol for wireless sensor networks is proposed in [11]. The proposed protocol targets WSN's applications having different types of data traffic. It is based on differentiating QoS requirements according to the data type, which enables to provide several and customized QoS metrics for each traffic category. With each packet, the protocol attempts to fulfill the required data-related QoS metric(s) while considering power efficiency. It is modular and uses geographical information, which eliminates the need of propagating routing information. For link quality estimation, the protocol employs distributed, memory and computation efficient mechanisms. It uses a multisink single-path approach to increase reliability. This protocol is the first that makes use of the diversity in data traffic while considering latency, reliability, residual energy in sensor nodes and transmission power between nodes to cast QoS metrics as a multiobjective problem. The proposed protocol can operate with any medium access control (MAC) protocol, provided that it employs an acknowledgment (ACK) mechanism LOCALMOR We define two kinds of sinks; primary sink and secondary sink, to which a separate copy of each message that requires high reliability is sent. A typical example of such a scenario is patient monitoring in a hospital room, where different health parameters are to be captured and forwarded to health care servers accessible by the medical staff. Traffic is diverse and may have different QoS requirements, depending on the monitored parameter and its value, the patient health situation, the patient context, e.g., regular monitoring versus monitoring in operating room, etc. Duplication toward a secondary sink may be useful if high reliability is required. Three different classes of QoS requirements are used in the proposed protocol: 1) energy efficiency (including both residual energy and the required transmission power), 2) reliability and 3) latency. The first requirement is traffic unrelated, contrary to the other ones. It can be viewed as application-related QoS metric that must be taken into account for all types of traffic, since ensuring a long network lifetime is essential for all applications. With these requirements, data traffic type may be split as shown in Table 1:

Table 1: Packets type in LOCALMOR

| Packet Type	Characteristic	Example
Regular traffic	No QoS	
Reliability-sensitive traffic	should be delivered without loss but can tolerate reasonable delay	file transfer
Delay-sensitive traffic	should be delivered within a deadline but may tolerate reasonable packet loss	video streaming
Critical traffic	high importance and requiring both high reliability and short delay	safety alarms in vehicular applications,
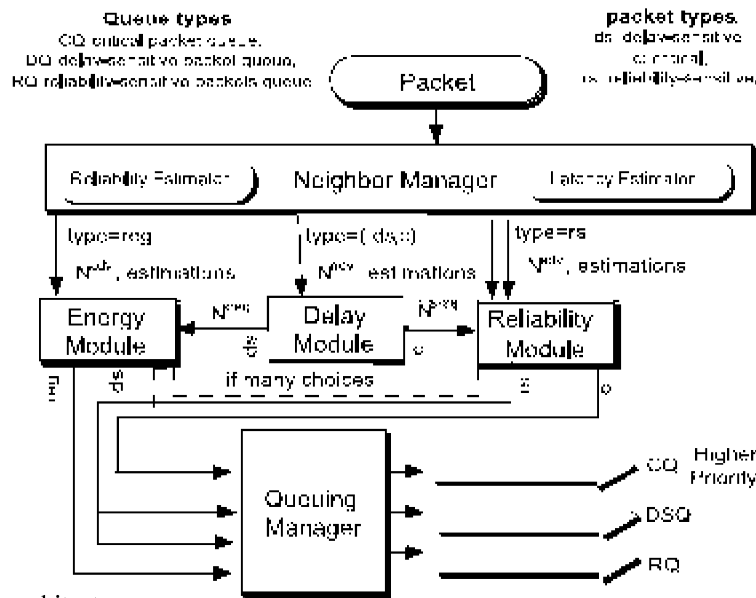
Fig. 6: LOCALMOR architecture

Following this classification, the proposed protocol is designed using a modular approach, aiming to ensure exactly the required QoS for each packet. A module is devoted to each QoS requirement, in addition to the queuing module and neighbor manager. The queuing module is responsible for implementing a priority multiqueuing strategy that gives more priority and it consequently ensures shorter latency, to critical and delay-sensitive packets. The neighbor manager runs the HELLO protocol that enables exchanging information between neighboring nodes and implements the link reliability and latency estimators. In LOCALMOR, the routing functions have been separated for multiple packet types; however, it uses fixed number of sinks (primary and secondary sinks) and all packets are blindly duplicated toward both the sinks, making it unscalable. Also, it increases the overhead of sending too many duplicate packets. Figure 6 shows the architecture of LOCALMOR.

EQGR (Energy-efficient Qos-besed Geographical Routing): EQGR [12] a new energy-efficient and QoS-aware geographic routing protocol is introduced for wireless sensor networks. EQGR maximizes the network lifetime and uses optimum cost function to select the best neighbor node. For minimizing inter-node and intra-node timeliness, we use two neighbor information routing tables for reliability and real-time domains. To minimize the queue waiting time for time-sensitive packets, scheduling policy considers different priorities for different types of data according to their criticality.

EARQ: Wireless industrial sensor networks are wireless sensor networks which have been adapted to industrial applications. Most techniques for wireless sensor networks can be applied to wireless industrial sensor networks. However, for industrial applications of wireless industrial sensor networks, new requirements such as real-time, reliable delivery need to be considered. The authors propose a new routing protocol for wireless industrial sensor networks, EARQ [13], which is a novel routing protocol for wireless industrial sensor networks. It provides real-time, reliable delivery of a packet, while considering energy awareness. In EARQ, a node estimates the energy cost, delay and reliability of a path to the sink node, based only on information from neighboring nodes. Then, it calculates the probability of selecting a path, using the estimates. When packet forwarding is required, it randomly selects the next node.

A path with lower energy cost is likely to be selected, because the probability is inversely proportional to the energy cost to the sink node. To achieve real-time delivery, only paths that may deliver a packet in time are selected. To achieve reliability, it may send a redundant packet via an alternate path, but only if it is a source of a packet. EARQ provides real-time communication without compromising the energy awareness of the existing energy aware routing protocol, EAR. It selects a path that expends less energy than others, among paths that deliver a packet in time. Sometimes, it selects a path that expends more energy than the optimal path, because the path is selected at random, according to a probability. This enables even distribution of energy expenditure to sensor nodes. In addition, EARQ provides efficient, reliable communication, because it only sends a redundant packet via an alternate path if the reliability of a path is less than a predefined value. The deadline, which is the maximum tolerable packet delay, must be carefully selected. The deadline must be the same as or longer than the minimum network delay. This paper estimated the minimum delay, to select a deadline given the density of sensor nodes and radio range. Simulation results showed that EARQ performs better than existing QoS routing protocols, in terms of reducing the number of packets that missed deadlines or were lost, while considering energy awareness.

RTLD (Real-time Routing Protocol with Load Distribution): Wireless sensor network (WSN) is a wireless ad hoc network that consists of very large number of tiny sensor nodes communicating with each other with limited power and memory constrain. WSN demands real-time forwarding which means messages in the network are delivered according to their end-to-end deadlines (packet lifetime). This paper proposes a novel real-time routing protocol with load distribution (RTLD) [14] that ensures high packet throughput with minimized packet overhead and prolongs the lifetime of WSN. The routing depends on optimal forwarding decision that takes into account of the link quality, packet delay time and the remaining power of next hop sensor nodes. RTLD consists of four functional modules that include location management, routing management, power management and neighborhood management. The location management in each sensor node calculates its location based on the distance to three pre-determined neighbor nodes. The power management determines the state of transceiver and the transmission power of the sensor node. The neighborhood management discovers a subset of forwarding candidate nodes and maintains a neighbor table of the forwarding candidate nodes. The routing management computes the optimal forwarding choice, makes forwarding decision and implements routing problem handler.

MCMP: Sensor nodes are densely deployed to accomplish various applications because of the inexpensive cost and small size. Depending on different applications, the traffic in the wireless sensor networks may be mixed with time sensitive packets and reliability-demanding packets. The goal of MCMP [15] is to provide soft-QoS to different packets as path information is not readily available in wireless networks. This protocol utilizes the multiple paths between the sources and sink pairs for QoS provisioning. Unlike E2E QoS schemes, soft-QoS mapped into links on a path is provided based on local link state information. By the estimation and approximation of path quality, traditional NP-complete QoS problem can be transformed to a modest problem. The idea is to formulate the optimization problem as a probabilistic programming and then based on some approximation technique, MCMP convert it into a deterministic linear programming, which is much easier and convenient to solve. More importantly, the resulting solution is also one to the original probabilistic programming.

$$\text{Minimize} \sum_{j=1}^{p} X_j$$

$$\text{Subject to } X_j d_j \leq D$$

$$r = 1 \prod_{j=1}^{p} 1 - X_j d_j^3 R$$

$$X_j = 0 \text{ or } 1, \text{ for all } j = 1, 2, \dots, P$$

Where, D and R are denoted as the delay and reliability QoS requirements respectively.

QoSNet: Numerous QoS routing strategies focus on end-to-end delays to provide time constrained routing protocols in wireless sensor networks (WSNs). With the arrival of wireless multimedia sensor networks, traffic can be composed of time sensitive packets and reliability-demanding packets. In such situations, some works also take into account link reliability to provide probabilistic QoS. The trade-off between the guarantee of the QoS requirements and the network lifetime remains an open

Table 2: Checklist for choosing QoS-based routing protocol

Protocol	Reliability	Real time	Energy Conservation
SAR	High	High	High
RAP	Low	High	Low
RPAR	Low	High	High
Speed	Low	High	High
MMSPEED	High	High	Low
MCMP	High	High	High
ReInform	High	Low	Medium
EQGR	High	High	High
EARQ	High	High	High
ERes-QoS	High	High	High
RTLD	High	High	High
DMQoS	High	High	High
DARA	High	High	High
QoSNet	High	High	High

issue, especially in large scale WSNs. The authors in [16] proposes a promising multipath QoS routing protocol based on a separation of the nodes into two sub-networks: the first part includes specific nodes that are occasionally involved in routing decisions, while the remaining nodes in the second sub-network fully take part in them. The QoS routing is formulated as an optimization problem that aims to extend the network lifetime subject to QoS constraints. Using the percolation theory, a routing algorithm is designed to solve the problem on the respective sub-networks. Simulation results show the efficiency of this novel approach in terms of average end-to-end delays, on-time packet delivery ratio and network lifetime.

DMQoS: Data-centric Multiobjective QoS-aware Routing Protocol for Body Sensor Networks: In DMQoS [17], the authors address Quality-of-Service (QoS)-aware routing issue for Body Sensor Networks (BSNs) in delay and reliability domains. They propose a data-centric multiobjective QoS-Aware routing protocol, called DMQoS, which facilitates the system to achieve customized QoS services for each traffic category differentiated according to the generated data types. It uses modular design architecture wherein different units operate in coordination to provide multiple QoS services. Their operation exploits geographic locations and QoS performance of the neighbor nodes and implements a localized hop-by-hop routing. Moreover, the protocol ensures (almost) a homogeneous energy dissipation rate for all routing nodes in the network through a multiobjective Lexicographic Optimization-based geographic forwarding.

Finally, table 2 provides a summary of all the protocols mentioned in this paper and provides a checklist that can help network designers to choose a suitable QoS-based routing protocol that can meet more than one QoS objective. There is always a trade-off while choosing a QoS-based routing protocol. A checklist has also been provided as a guideline to select a suitable routing protocol.

CONCLUSION

The QoS-based routing protocols for wireless sensor networks have been a subject of quite a number of investigations in recent years. The QoS-based routing protocols discussed in the previous section have their own advantages and disadvantages. Choosing a suitable QoS-based routing protocol is a very challenging task and must take into consideration the following factors: (1) the size of a network, (2) the lifetime of a network, (3) environmental conditions and (4) types of applications. A good routing protocol needs to provide reliability and energy efficiency with low control overhead. This paper presented a survey of most recent QoS-based routing protocols for WSNs. The surveyed protocols showed that QoS-based routing can improve network performance in terms of delay, throughput, reliability and life time. Selection of a QoS-based routing protocol depends on a particular application and trade-offs. Some of the objectives are energy efficiency, low overhead, reliability and scalability.

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