REAL-TIME ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORKS: A SURVEY

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ABSTRACT

Wireless sensor networks can be termed as a new generation of distributed embedded systems that has a capability of meeting broad range of real-time applications. Examples include radiation monitoring, fire monitoring, border surveillance, and medical care to name but a few. Wireless sensor networks that are deployed in time/mission-critical applications with highly dynamic environments have to interact with the physical phenomenon under stringent timing constraints and severe resource limitations. For such real-time wireless sensor networks, designing and developing a real-time routing protocol that meets the required real-time guarantee of data packets communication is a stimulating field of study that raised many challenges and research issues. In this paper, we present a comprehensive survey of real-time routing protocols in WSN, by discussing each protocol with its key features. Finally, we concluded this paper with open research issues and challenges of real-time routing in WSN.

KEYWORDS

Wireless Sensor Networks (WSNs), Real-Time routing (RT), Hard Real-Time (HRT), and Soft Real-Time (SRT).

1. INTRODUCTION

Currently, the progression of wireless technology in various application areas including military, industrial, environmental, medical, crisis management, smart environments to name but a few, leads to the emergence of wireless sensor networks (WSNs) at an accelerated pace to collect and communicate information from remote locations wirelessly. A wireless sensor network (WSN)[1] can be treated as a co-operative network of small size, low power, smart devices named as Nodes or Motes, which have the capability of sensing a physical phenomenon (like temperature, humidity, pressure, vibration…etc) and relay the same or processed information to a sink via wireless links possibly with multiple hops between these nodes. The unique characteristics of WSN such as small size, low power consumption, autonomous, mobility, dense in volume, self-healing and self-organizing poses some constraints in terms of power consumption, storage, processing capabilities and bandwidth requirement [2].

Even though energy efficiency is of a major concern, providing the required Quality of Service (QoS) in terms of timeliness, reliability, fault tolerance, is also of a major concern for the respective applications. For an instance, a wireless sensor network which is deployed in a nuclear power plant to monitor the release of radioactive fluids, has to detect the leakage at an infant stage and the corresponding alert has to relay to the control room with in a defined dead time, otherwise

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it may cause catastrophic effect. Likewise, WSNs have gained an immense attention for their ability in meeting the real time QoS guarantee in many time critical scenarios. In general, real time packet communication guarantee can be categorized as i) Hard Real Time (HRT) ii) Soft Real Time (SRT) [4-8]. HRT should support a deterministic dead time. That implies, delivery of a message after the dead time is considered as a failure, sometime it may lead to a catastrophic effect. On the other hand, SRT supports probabilistic dead time, which allows some sort of latency in message delivery. Providing a real time communication in case of WSNs is a challenging task because of the highly unpredictable nature of wireless links, variable data packets relaying and energy, bandwidth constraints [15]. The requirement of real time guarantee can be addressed from different mechanisms in different layers of protocol stack of WSN. I.e. by means of an efficient protocol in MAC layer, efficient routing protocol in network layer, by in-network data aggregation mechanism and even cross layer design approach [24]. In this paper, we presented a comprehensive survey of various real time routing protocols in WSNs, which meets the requirement of timeliness along with other QoS in time critical applications.

2. REAL TIME ROUTING IN WIRELESS SENSOR NETWORK

Even though the MAC layer mechanisms deliver information by considering real time needs, its effect remains local only. Therefore, it is the task of a real time routing protocol to satisfy the real time end-to-end guarantee globally. Without loss of generality, a real-time routing protocol is the one, which plays a prominent role in achieving real time communication guarantee in time critical applications of WSNs [4-8]. By seeing above stated information regarding real time routing, it is reasonable to say that the designing of a real time routing protocol is a quite challenging task. In papers [5],[6], [7], authors clearly summarized various design issues like energy consumption, fault tolerance, scalability, network dynamics, transmission media, data reporting model and other QoS to be consider while a designing real time routing protocol.

3. REAL-TIME ROUTING PROTOCOLS

RAP: [10] RAP is a Real-time communication Architecture for large-scale WSNs. For distributed micro-sensing applications, RAP provides a convenient, high-level query and event-based services, which is based on a novel location-based addressing model supported by a lightweight protocol stack.. Sensing and control applications interact with RAP through a set of APIs. A Query/ event service layer submits desired query or event registration to the physical environment. The occurrence of the event will automatically trigger the query and communicate the query results to the base station via local coordination and sensor-base communication. The

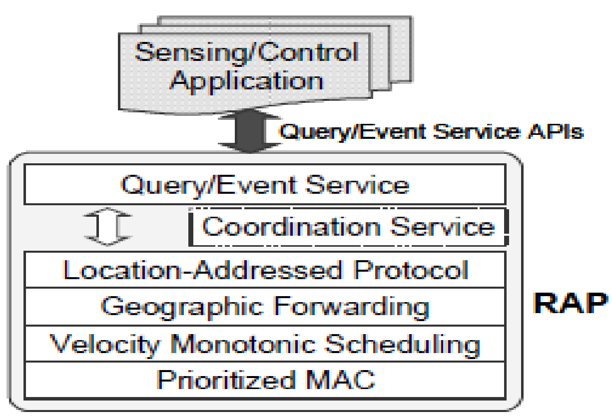

Figure 1. RAP Communication architecture model [9]

coordination service provides the local area coordination among the sensors in the sensed area by dynamic group management and aggregates data to generate the reliable data for the sensor-base communication. A bottom four layered network stack of the RAP architecture shown in Figure 1 supports the sensor-base communication. Location-Addressed Protocol (LAP) is a connectionless transport layer protocol where all the messages are addressed by location rather than IP address. The proposed LAP provides three types of communication namely unicast, area multicast and area anycast. The proposed Geographic Forwarding (GF) routing protocol, make a greedy decision in forwarding a packet to a neighbor node. A novel packet scheduling policy named Velocity Monotonic Scheduling (VMS) is been proposed, which is both deadline-aware and distance-aware. VMS is based on the notion of packet requested velocity i.e. the priority of the packet is assigned based on its requested velocity.VMS assigns highest priority to those packets having high requested velocity and lowest priority to those packets having less requested velocity which leads to the decrease in packets deadline miss ratio. Two priority assignment policies namely Static Velocity Monotonic (SVM) and Dynamic Velocity Monotonic (DVM) are been investigated in the proposed protocol. SVM assigns a fixed requested velocity for a packet on each hop, which is based upon the distance from the current node to the destination and deadline (D). DVM dynamically re-calculates the requested velocity of a packet at each node, which is based upon the distance between the current node to the destination, deadline (D) and elapsed time of the packet. If the incoming packet velocity is less than the desired velocity, DVM dynamically increases the required velocity so that the packet can reach the destination within dead time. A prioritized MAC layer provides a distributed prioritization on packets from different nodes that helps in meeting global prioritization of packets. Simulation results showed that the RAP is get successful in achieving low Deadline Miss Ratio (DMR). However, RAP is depending upon the notion of velocity, which is not sufficient to provide high throughput in wireless communication, especially in case of real-time communication applications.

SPEED: [9] Stateless Protocol for End- to-End Delay (SPEED) is a real-time communication protocol for the wireless sensor networks, which is a stateless and localized routing algorithm. SPEED is designed to provide a soft real time communication services with a desired uniform delivery speed across the sensor network where the end-to-end delay is proportional to the distance between source and the destination. It uses a stateless approach, which stores the information of neighbor nodes in neighborhood table rather than storing routing

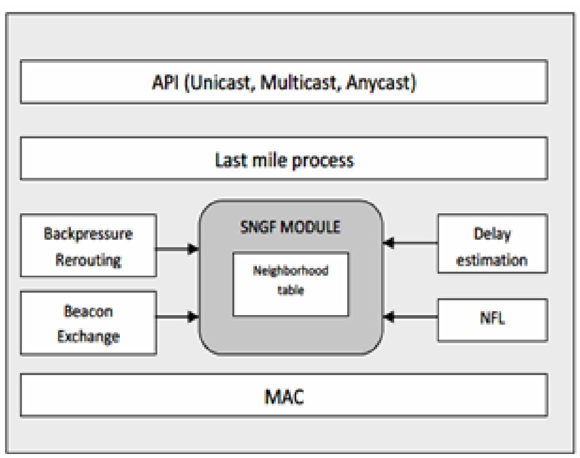

Figure. 2 SPEED Protocol architecture [10]

table of whole network. The protocol architecture of SPEED is shown in Figure 2. This protocol provides three types of communication services through API is namely, RT-unicast, RT-area multicast, RT-area anycast for wireless sensor networks. The last mile process intended to support the above-mentioned three communication services. Stateless Non-Deterministic Geographic Forwarding (SNGF) is a routing module responsible for selecting the appropriate forwarding node in the neighborhood table that meets the desired delivery speed that in turn balances load in each flow among multiple concurrent routes. A Neighborhood Beacon Exchange module provides a geographic location of the neighbors to a node by periodically broadcasts a beacon packet to its immediate neighbors. This geographic location helps SNGF to support geographic based routing. Delay estimation module is intended to estimate the single hop delay that helps in making routing decisions. A novel Backpressure re-routing algorithm helps in re-route packets around large-delay links (i.e. congestion) with minimum control overhead. SPEED handles the void in the same way as it handles congestion areas by using backpressure re-routing algorithm. It uses an effective approach namely Neighborhood Feedback Loop (NFL) to maintain the system performance at a desired value by keep up the desired single hop delay. The main aim of NFL is to maintain the miss ratio, as low as possible, desirable is zero. Performance results showed that the SPEED performs well in terms of deadline miss ratio and it effectively manages the void and congestion scenarios within the network. However, the main disadvantage of the proposed protocol is that it does not consider the energy metric.

Akkaya et al: [11] proposed an energy-aware delay-constrained routing algorithm for wireless sensor networks which is an energy-aware approach for routing delay-constrained data. The proposed approach is based on the two-step strategy incorporating both link-based costs and delay constraints. In first step, identification of the some forwarder candidate paths takes place without considering the end-to-end delay constraints. Each of these links is associated with a certain cost function, which depends upon the distance between the present node and the forwarder node and residual energy of the forwarder node of the link. In order to get the ascending set of least link cost paths, they used an extended version of Dijkstra's algorithm. In the second step, they imposed delay constraints upon these candidate paths and the path that meets the end-to-end delay requirements will be choose as a next forward path. End-to-end delay bound for real-time data is achieved by using a Weighted Fair Queuing (WFQ) based packet scheduling technique in each sensor node. This scheme involves in regulation of the incoming traffic from the sources by using the leaky-bucket traffic-regulation mechanism and separates the real-time traffic from non-constrained traffic with the usage of two different queues in each node to provide soft real-time guarantees for data. The proposed algorithm balances the energy and timeliness goals of the network and prevents the potential excessive topology management overhead. Simulation results showed that this protocol performs well in terms of miss ratio and average delay and the authors stated that, it provides at least 80% on time delivery of real-time data even though network is in congested scenario.

MM-SPEED: [12] is a Multi-path and Multi-speed real-time routing protocol which provides multiple probabilistic QoS guarantee in wireless sensor networks based on the work of SPEED[10]. MM-SPEED provides QoS in terms of two distant domains namely timeliness and reliability, so that the packets can choose the any one of the QoS or both depending upon their requirement. Unlike the SPEEED, MM-SPEED provides multiple network wide speed options instead of single network-wide speed guarantee to address the Qos in terms of timeliness. For achieving the QoS in terms of reliability, MM-SPEED uses the probabilistic multipath forwarding. For achieving Qos guarantee in terms of timeliness, MM-SPEED provides multiple layers of network wide speeds augmented by two novel techniques namely; virtual isolation and dynamic compensation. By using a virtual isolation technique, classification of incoming packets according to their speed classes takes place and placed them in an appropriate queues, which aid in minimizing the effect of lower speed packets on the delays experienced by the high-speed packets. The packets in the highest priority queue are served first in FIFS fashion. Virtual isolation in a node avoids intra-node priority inversion only. Therefore, in order to provide the distributed prioritization, which minimizes the inter-node priority inversion, a network layer takes the support from the MAC layer. It uses a notion called dynamic compensation, which compensates for inaccuracy of local decisions in a global sense as a packet progress towards its destination. I.e. when a packet arrives to a node with the speed less than the desired speed, dynamic compensation enhances its speed to required speed, which ensures high probability of meeting end-to-end deadlines. In order to provide the service differentiation in terms of reliability, MM-SPEED used the principle of redundancy i.e. the more paths to deliver, the higher the probability that the packet reaches its final destination. Performance results showed that the MM-SPEED performs well in providing Qos in terms of timeliness and reliability or both for the various traffic types. Like that of SPEED, energy metric is not considered in the protocol design.

Mahapatra.A et al: [13] proposed an energy-aware routing scheme for real-time traffic in wireless sensor networks. While routing the real-time data packets, the proposed routing scheme considers packet delay, nodes energy utilization, network congestion at the intermediate nodes to mitigate the routing delay across the network. It also provides the reliability by using the concept of data redundancy in the form of duplicating the packet in the source node. In the proposed scheme, by exchanging a periodic beacon to the immediate neighbors each node maintains information about its immediate neighbor's in the form of neighborhood table. This table contains the geographic location of a particular node, energy left, the estimated time delay, mobility factor of that node. Once a node has a packet to send, routing protocol firstly calculates a factor called urgency factor (UF) = D/TL; where D=distance between current node to the destination node, TL=remaining time to meet the deadline. Based on the calculated urgency factor, routing protocol dynamically calculates a distance „r‟ to where the packets need to be pushed closer to the destination. The proposed routing protocol provides trade-off between the energy factor and delay factor by means of prioritization of real time data and non real time data. That is, for time critical data having high urgent factor is assigned with highest priority for the delay factor and lowest priority for the energy factor. Whereas, for the non real time data having low urgent factor is assigned with highest priority for energy factor and lowest priority for the delay factor. If a node has both time-critical and non-time critical data, then all the data is buffered and the most critical packet having high urgent factor is served first. Once the prioritization had done, the session source node selects two best nodes from the forwarder nodes set, and sends a copy of data packet to both nodes. This sort of duplication of data packets increases reliability of data packet delivery. They also introduced an adaptive prioritized MAC layer, which assigns higher priority to real-time packets and reduces the MAC layer delay for time critical data. This is done by maintaining two different interfacing queues for both real-time data and non real-time data, and then assigning highest priority to the real-time packet having highest urgent factor. Simulation results showed that the proposed scheme performs well in terms of end-to-end communication guarantee for high traffic real-time packets.

Pothuri et al: [14] **i**nvestigated on Delay-constrained energy efficient routing problem (DCEERP) in wireless sensor networks and proposed network architecture and a routing framework that enables to model the access delays caused by the MAC layer, which in turn enables to better estimate the end-to-end delays along the various paths from source node to sink node. By assuming the sensing field be geographically divided in to various cells, authors proposed an network architecture, where the data transfer from the sensor node to the sink takes place in two phases namely, intra-cell phase and inter-cell phase. In intra-cell phase, by using the short-range radios the end devices relay the sensed data directly to the gateway of that particular cell within the time „d11‟ which is less than required end-to-end delay „d1‟. In inter-cell phase, a gateway relays the gathered information to the sink node T by using direct relaying through long-range radios or multi hop relaying through short-range radios within the time d1-d11. During multihop relaying in inter-cell phase, each gateway of a cell relays data to the immediate neighbor gateway, which helps in maximization of energy efficiency. At first in the proposed scheme, finding a set of paths from the source to sink nodes takes place and indexed them in the order of their energy consumption. Later end-to-end delay is estimated along these set of paths and the one that has the lowest index that too which satisfies the energy constraints is choose for the relay of data. Numerical results showed that the proposed solution is effective in terms of delay constraint and energy efficient as well.

Ergen et al: [15**]** proposed an energy efficient routing algorithm with delay guarantee for wireless sensor networks. At first, without considering the delay constraint they formulized the lifetime maximization of a node as a Linear Programming (LP) problem and proposed a centralized energy efficient routing protocol for the centralized implementation of this LP problem. The proposed centralized algorithm determines the optimal path from each sensor node to the Access Point (AP) based on the network topology and the packet generation rates at each sensor nodes. Nevertheless, solving the LP problem requires whole network's knowledge and packet generation rate at each node and involves too many computations at a sensor node. Therefore, they proposed a distributed energy efficient routing algorithm that approximates the LP solution. This approximation helps in incorporating the time constraints into the routing protocol. The main task of this distributed energy efficient routing is to get optimal lifetime as close as possible while periodically executing a distributed routing algorithm based on the remaining and initial energy of each node. They presented two distributed algorithms namely; least sum-cost path algorithm and least max-cost path algorithm, aiming at minimizing the cost of the routing path from each sensor node to the AP. Later they extends the energy efficient routing protocol to provide a delay guarantee by limiting the length of the routing paths form each node to the AP while generating energy efficient paths. The proposed protocol suits well for the application that demands both energy aware and timeliness.

RPAR: [16**]** Real-Time Power Aware Routing protocol is an energy efficient, real-time routing protocol for WSNs which provides energy efficient real time communication by dynamically adapts its transmission power and routing decisions based on workload and packet deadlines. The key feature of RPAR is its adaptive nature; i.e. when the deadlines are tight; it trades energy and capacity to meet the desired time constraint, whereas at the time of loose deadlines, it lowers the transmission power to increase the throughput and to reduce the energy consumption. RPAR protocol architecture consists of four major modules as follows. 1) Dynamic velocity assignment module- maps a packet deadline to a required packet velocity V_{req}. That is, when a node *S* has a packet to forward, it uses a velocity assignment module to calculate the required velocity which is based on the remaining distance between the present node and the destination and the packets slack or time to live (TTL). It also prioritizes the packets based on their urgencies or deadlines. 2) Delay estimator module-responsible for finding the one-hop delay of different forwarding choices. 3) Forwarding module-intended to forward the packet to the most energy-efficient forwarding node that meets the required packets speed. 4) Neighborhood manager module-responsible for quickly and dynamically discovers eligible forwarding nodes that are energy-efficient and manages the neighborhood-table effectively. For the discovery of new forwarder nodes, it uses two mechanisms namely power adaptation and neighborhood discovery scheme. In Power adaptation mechanism, the transmission power is increases to meet the required velocity for the existing neighbors in the neighborhood table. In neighborhood discovery scheme, discovery of new neighbors that meet the required velocity takes place by sending the Request to Route (RTR) packets to the neighbors. The proposed power adaptation and neighborhood mechanisms are on-demand rather than the periodic beaconing. This reactive approach helps in discovery of the neighborhood quickly along with low communication and control head. Performance results showed that it performs well in terms of deadline miss ratio and energy consumption.

FT-SPEED: [17] Lei Zhao et al proposed a fault-tolerant real-time routing protocol called FT-SPEED for the wireless sensor networks. FT-SPEED is developed based on the work of SPEED [10]. It has all the components same as that of SPEED, except the void avoidance scheme. The proposed novel void announce scheme and void by pass scheme outperforms void avoidance scheme of SPEED. Void announce scheme is proposed to avoid the packets be delivered to the nodes which has stuck node as their forwarding node i.e., the packets could be avoided being sent to the void area by using the void announce scheme. When a node receives a packet for the target and if it finds a forwarder node set is as null, then node will know itself as a stuck node and broadcasts backpressure beacon to all its neighbors‟ nodes so that no nodes in a network will send the data to the void areas nodes. By this way when there is a void in the network, void area position message will quickly broadcasted in the whole network. In order to deliver a packet without dropping when it reaches a void region edge, a novel two side's void by passing scheme is proposed to guarantee the real-time requirement by delivering the packets to the destination. The void edge nodes will try to bypass the void and send the packets along the void edge until it find the node nearer to the destination. Simulation results showed that the FT-SPEED keeps the packet delivery ratio as high even though the void diameter in a network is large.

EDRP: [18] Pourkabirian et al proposed an Energy-aware, Delay constrained Routing Protocol (EDRP) for WSNs by using Genetic Algorithm (GA). The proposed protocol is energy aware, QoS routing protocol that can run effectively with real-time traffic. The proposed protocol is emanated by SPEED[10], with the key design goal of to support a soft real-time communication services with a desired delivery speed across the sensor network along with the optimal usage of energy in nodes by distributing balanced loads. That is, EDRP formalizes the tradeoff between the QoS (timeliness guarantee) and energy consumption of the sensor networks. In the proposed scheme, authors represented a network of n nodes by a chromosome of n bits. These chromosomes exchange information by crossover and produce new chromosomes and the probability of an individual chromosome surviving a crossover depends upon its fitness value. The parameters like single hop delay, speed, energy consumption determines the fitness function of a particular chromosome. In genetic algorithm, fitness of a chromosome is evaluated by the weight function that defining the problem. As the fitness of a chromosome is high, the chances of survival of chromosome are higher. In general, a population consists of several chromosomes and the best chromosome is used to generate the population. In the proposed approach, GA keeps the certain number of best individuals from each generation and copies them into new generation. This new generation will have some of the individuals from the previous population and others that are evolved because of crossover and mutation. Because of the fewer nodes in the Forwarder Set (FS) and few node runs, this algorithm the proposed approach acts as a lightweight i.e. less overhead and quickly finds the optimal solution. The fitness function of a chromosome is designed to minimize the energy consumption and to consider the end-to-end delay for real time traffic. Simulation results showed that the EDRP outperforms SPEED in terms of network lifetime and energy consumptions while meeting the required delay constraint.

ARP: [19] is an Adaptive Real-Time routing scheme that can satisfy the requirement of real time communication service for the time critical applications. The proposed scheme provides different real-time levels for different applications while exploring the tradeoff between energy consumption and real-time transmission. It dynamically changes packets requirement to transmission speed and adjusts their real-time priority during the end-to-end transmission period by using two special fields in each packet namely RT field and TTL. RT field is used to identify the packet as a time critical packet and the Time to Live (TTL) field is used to know the remaining time to packet expiration. When a node receives a packet to send, first it checks whether the packet is time critical or not by using RT field. If it is not a real time packet, it sends to the routing scheme module for selection of appropriate next hope node. If it is a real time packet then it will be send to the real-time level adjustment module where the local transmission rate for the packet to reach the destination is calculated based on the node location and TTL value in the packet header. This scheme comprises of the following modules like, 1) Cache Queue- is a bi-directional linked list that stores the data packet information. 2) Real-time transmission level adjustment module-intended to ensure the end-to-end transmission rate of data packets within the dead time. 3) Routing selection module, which is responsible for choosing appropriate route for data packets. 4) Neighbors and links states updating module-intended to collect enough information for route selection module to choose the next hop node for packets. In order to maintain a tradeoff between the energy consumption and real time transmission; non real-time packets will be sent to route selection module to choose its next hop, whereas the real –time packets will be sent to the real-time adjustment module, which calculate out the smallest local transmission rate for the packet to reach the destination within the dead-time. Simulation results showed that, ARP performs well during network over load conditions and in terms of control cost.

Khalid et al: [20] proposed a new routing protocol for wireless sensor networks which has the ability of providing reliable and real-time communication services along with energy awareness by differentiating packets based upon their urgency and importance. The proposed protocol dynamically maintains a tradeoff between the energy consumption and message latency while communicating the time-critical and non time-critical data packets. I.e. while routing real-time packets with tight-deadlines a higher transmission power is used so that latency is reduced. In order to provide differentiation routing service between the real-time data packets and non real-time data, two cost functions namely CostI (time awareness) and costII (energy awareness) are defined on each particular link and node separately. When the source node receives these two cost functions for all its neighbors, then it calculates propagation time T_P for all its neighbors. If time to live T_L of the packet is less than T_P of all paths of the neighbors then that particular packet is simply discarded with in turn saves the energy and minimizes the network congestion. Whereas, if T_L is greater than $T_{P,i}$ of node ‘ i’, then highest priority is given to that node ‘ i’ and data is forwarded through that node. At the same time if more than one path has the T_P less than T_L, then the path having less costII function i.e. less energy consumption path is given with highest priority. In case non real-time data packets node considers only costII function, which selects the energy efficient path without considering time constraints. The same procedure will be run at each node before forwarding packets to the neighbor nodes. Performance results showed that the proposed protocol provides automatic adaptation to different routes when network condition changes and maintains its robustness at the situations of unpredictable link failures.

Lingfeng Yuan et al: [21] proposed an energy efficient real-time routing protocol for wireless sensor networks. They proposed a simplified route discovery process by separating the whole path’s end-to-end delay into the sum of point-to-point “Constrained Equivalent Delay *(*CED*)”*. Each intermediate node can independently decide its next forwarding node according to the value of the links CED that avoids wasteful calculations, reduces the overhead greatly and simplifies the route discovery process. The proposed real-time routing protocol with constrained equivalent delay (CED) involves two phases; Candidate Selection Function *(*CSF*),* for selection of an optimal forwarding node with in Forward Candidate Set (FCS). Candidate selection function is termed as the ratio of the actual link’s delay to the link’s CED. The sender Si compares each element in the Forward Candidate Set (FCS) by the CSF and chooses the node having least CSF as a optimal forwarding node. A method of adaptive selection adjustment is proposed, to automatically adjust the constraints for the selection of the forwarder node when there is no candidate is available according to the constraints of ET. After receiving replies, node runs the same CSF to find the optimal forwarding node. This process continues until the forwarder node is the sink node. Then the sink node sends path establishment information along the discovered routing path. After receiving path establishment information, the source node sends the actual information to the sink node. Simulation results showed that this protocol is succeeded well in achieving lower energy consumption, lower end-to-end delay along with consistent success link ratio.

Min Chen et al: [22] proposed a Directional Geographic Routing (DGR) for real-time video communications in wireless sensor networks. DGR constructs an application specific number of multiple disjointed paths for a video sensor networks (VNs) to transmit parallel Forward Error

Correction (FEC)-protected H.26L real-time video streams under a number of resource and performance constraint (such as band width, energy, and delay) environments. In the proposed scheme, a single video stream is divided into multiple sub-streams, and exploits multiple disjoint paths to transmit these sub-streams in parallel. The concept of multipath routing in the proposed scheme is to facilitate the delivery of video stream in multiple flows whereas FEC coding relieves the responsibility of the reliable data delivery in routing layer. The key features of Directional Geographic Routing (DGR) include; next hop node selection strategy, Path repair mechanism, Dead-end problem handling. Next hop node selection strategy uses a PROB message to establish a direction-aware path. For route discovery, source node initiates this PROB message and selects the next hop forwarder. The selected next hop forwarder node broadcasts this PROB message to find its next hop forwarder and this process will continue until the next hop forwarder is a sink node. In path repair mechanism whenever a node „i‟ in a path fails, then the DGR protocol in its upstream node will broadcasts a PROB message immediately to select the different next hop node by using next hop node selection strategy. DGR handles dead-end problem very effectively. Dead end problem arises when is a packet reached to a node with no neighbor has closer hop distance to the destination. When next hop node selection strategy fails to find the optimum forwarder node, then DGR enters into greedy mode to select the next hop node, which is nearer to the destination. If in the greedy mode also a node does not have a neighbor node that is nearer to the sink, then DGR meets the dead end mode and the packet forwarded in recovery mode. I.e. the packet is routed according to the right-hand rule, which is a well-known concept to traversing mazes. They proposed hybrid video stream broadcasting and sub-streams unicasting scheme based on multiple disjoint paths that has been pre-established between the source VN and the sink using DGR scheme, which is presented above. Network life time, number of successful frames received by sink before life-time , average end-to-end packet delay, energy consumption per successful data delivery, peak signal to noise ratio (PSNR) are the performance metrics evaluated and performance results shown that DGR achieves reliability, energy-efficiency and timely packet delivery to support real-time video service . One important limitation is; DGR does not work well when a number of VN send video to the sink simultaneously.

RTLD: [23**]** Real-Time routing with Load Distribution (RTLD) is a novel real time routing protocol which has capability of delivering time-critical data packets within the dead time with minimized packet overhead along with the prolonged lifetime. In this protocol, in order to forward a data packet from a source node to destination, a new type of communication in WSN is proposed called Geodirection-Cast forwarding that combines the geocasting with the directional forwarding. Based on the Packet Reception Ratio (PRR), remaining power of sensor nodes and packet velocity over one-hop, RTLD computes optimal forwarding node to forward the incoming real-time data packet. The key features of this protocol are; Data throughput is improved because of choosing the links having the best link quality, real-time delivery guarantee is ensured because of using the maximum packet velocity and network lifetime is increased to the great extent because of using the nodes having the highest remaining energy. RTLD routing protocol architecture comprises of four modules. 1) Routing Management module- intended to compute the optimal forwarding choice and to make the respective forwarding decision. It consists of three-sub modules namely optimal forwarding calculation module, routing problem handler, forwarding mechanism module. Optimal forwarding mechanism calculates the optimal forwarding node based on link quality (PRR), packet velocity and remaining energy. Routing problem handler solves the problem arise due to network holes by using two-recovery methods; fast recovery method using power adaption and slow recovery method using feed control packet. Unicast forwarding and the geo-directional-cast forwarding are two types of forwarding mechanisms in RTLD provided by the routing management module. 2) Location management module- is responsible for determining the localized information of sensor nodes in grid of WSN. 3) Neighborhood management module- is to discover the forwarding candidates that are mostly useful in meeting end-to-end delay requirement, optimal PRR, remaining power and maintains the discovered information in the form of neighborhood table. 4) Power management module- is intended to determine the state of the transceiver and to select the transmission power of the sensor node. Power management module increases the lifetime of the network by minimizing the energy wastage through idle listening and control packet over head. Simulation results showed that RTLD gives high performance in terms of real-time packet delivery ratio, through, control packet overhead and power consumption.

THVR: [24] Two-Hop Velocity based routing protocol (THVR) is a two-hop neighborhood information-based geographic routing protocol which is proposed to support the QoS in terms of real-time packet delivery for WSN along with the better energy efficiency. In this protocol, routing decision is made based on the two-hop velocity integrated with energy balancing mechanism. The advantage of using two-hop information for routing over single- hop is that number of hops required to transmit the data from source to destination is decreases significantly. THVR uses the advantages of two-hop neighborhood information over single-hop neighborhood information that is not there in previously proposed protocols like SPEED, MM-SPEED, FT-SPEED etc. In a strict sense the idea of two-hop information, based routing is tradeoff between performance and complexity cost. In the proposed scheme, authors adopted the approach of mapping packet deadline to a velocity, which is well suitable metric for delay constrained packet delivery. The key features of the proposed protocol include; it achieves lower Deadline Miss Ratio (DMR) along with the higher energy efficiency by using novel two hop node information based routing. An effective energy balance throughout the network is achieved by using a mechanism that releases the nodes, which are frequently used as a forwarder node. Forwarding metric in THVR is similar to that of SPEED where the packet deadline is mapped to the velocity requirement. In THVR, when a node has a data to forward it will search the node having highest velocity in the two-hop neighborhood before making the forwarding decision. The proposed delay estimator module calculates the packet delay from the sender to its potential forwarder. This estimated delay plays an important role in calculation of packet delivery velocity that meets the deadline requirement. For the delay-estimation, they used a novel method named Window Mean with Exponentially Weighted Moving Average (WMEWMA). In order to balance between the energy efficiency and real time guarantee, they proposed a novel mechanism called Initiative Drop Control mechanism (IDCM) that drops the packets when there is no node in two-hop forwarding set meets the required velocity. In a strict sense, it will not simply drop the packets that doesn't meet the velocity requirement, but the packets which are still near to the source that cannot meet the velocity is only dropped in earlier. Performance results showed that THVR works well in enhancing real-time delivery by an effective integration of two-hop information and outperforms SPEED in terms of DMR, energy efficiency. However, using more than two-hop information is not a good idea, because it increases complexity cost.

Li-Ming He et al: [25] proposed a novel-real-time routing protocol for wireless sensor networks, having main objective of guaranteeing the real-time communication along with energy-efficiency of a real-time data. The proposed protocol comprises of three phases; Real-time route tree construction phase, Data delivery phase and Route update phase. Real time route tree construction phase is a highly efficient real-time route discovery process that finds the optimal real-time route from any node of the network to the sink node. Route discovery process involves; when a node has an interest to an event, then it become a sink node and broadcasts a special kind of query messages named as tree-construction messages to all the nodes in a network. Then the sink node is become the root of the tree and it has a level zero. Each node in a network contains a local register having similar structure as that of tree-construction message in addition with time stamp field. When the broadcasted tree-construction messages reached to a particular node of a network it copies the interests in tree-construction message, records the time of message arrival in time stamp field, and assigns itself a level, which is one greater than message sender node. Thus, the node enters in to real-time routing tree and became the child to the message sender node. This process is continues until the real time route tree for the entire network is get complete. Therefore, real-time route tree is routed at sink node and is composed of multiple real-time routes from any node in network to the sink node. In data delivery phase, when a node has an event, then it searches for the corresponding interest in its local register. If there is any interest that is copied from tree-construction messages from sink matches with the present interest of a sensed event, then the particular node become the source node and sends the data through the discovered real-time route having less time stamp i.e. less time to message delivery. Real time guarantee is assured because of the delivery delay of sensed data is minimal. Routing update phase is responsible in finding the sub-optimal real-time route between the source and the sink to avoid usage of same optimal path frequently. This usage of sub optimal paths avoids the depletion of power of the nodes within the optimal path and thereby avoiding problem due holes formation in network. A novel route monitoring and reporting algorithm is proposed for the controlled maintenance of transitions among these three phases.

DMRF: [26] Guowei Wu et al proposed a Dynamically Jumping Real-time Fault-tolerant routing protocol (DMRF) for wireless sensor networks. The proposed protocol works in two data transmission modes: Hop-by-hop mode and jumping transmission mode. In hop-by-hop mode, each node uses the remaining transmission time of the real-time data packets and the state of the Forwarding Candidate node Set (FCS) and then dynamically selects the next hop node that is used as a forwarder for minimum number of times. By this, the average energy cost of each node can be balanced thereby network lifetime can be prolonged. In situations like, node failure, network congestion ,void regions, or the remaining transmission time of data packet is near to deadline, then hop-by-hop transmission mode switches to jumping mode which is intended to reduce the transmission delay, and thereby ensuring the real time data transmission. The transmission process in the proposed DMRF protocol is divided into five stages; Initialization phase, Data Transmission phase, Jumping Transmission phase, Adjusting Transmission phase and Transmission Ending phase. In Initialization phase, DMRF initializes the neighborhood nodes list, Forwarder Candidates Set list (FCS), Jumping probability table and State list that contains the information of congestion, failure nodes and information of voids. After initialized above-mentioned list, DMRF will initialize the data transmission phase. In Data Transmission phase, DMRF first checks for nodes that are failed, congested, voids in the FCS and also it checks for whether the remaining transmission time of data packet approach to the dead time. If none of the above mentioned conditions are happen, then DMRF works in traditional hop-by-hop mode that dynamically select the optimal neighbor depends upon the state of the FCS and location information. If anyone or the combination of above-mentioned condition happens, then DMRF switched to Jumping transmission node. In jumping transmission phase, DMRF first adjusts the status of nodes in FCS and calculates the corresponding jumping probabilities. By using this jumping probability, DMRF selects the next hop node that allows the data packets can jump over the failure nodes, congestion nodes, and void regions. It also reduces the transmission delay and there by ensured the real-time transmission for those packets where the remaining transmission time is near to the deadline. Adjusting transmission stage first checks result of jumping transmission phase for success or failure, and then adjusts the jumping probabilities according to it and feedbacks the information to the upstream node. Transmission end phase checks for the sink node, if it is not a sink, then above discussed process continues until the sink node reaches, once the sink is reached, the transmission is finished. Simulation results showed that the DMRF can not only efficiently reduces the effects of failure nodes, congestion and void area, but also performs well in terms of successful transmission ratio, lowering the transmission delay, reducing the number of the control packets, prolonging the network lifetime.

PATH : [27] Parvaneh Rezyat et al proposed a novel real time routing protocol named “Real-Time Power-Aware Two Hop routing (PATH).” This protocol uses the concept of using the two-hop neighborhood information rather than using only one-hop neighbor information that leads to lower the number of hops and helps in better choice for routing decisions. An Effective power control mechanism is implemented for improving link quality and reducing the delay as well. In a strict sense, PATH protocol is nothing but the integration of power control concept with Two-Hop Velocity based Routing (THVR). Power control mechanism used in this protocol manages the tradeoff between energy consumption, packet delay and network capacity. The key components of this protocol are: 1) Forward policy metric, which selects one energy efficient path that can provide required data delivery speed at each hop. 2) Delay estimator module-estimates the link delay to update the information for the forwarding policy. Whenever PATH cannot find any two-hop neighbor that can provide required velocity power adaption scheme will be invoke to discover neighbors that can achieve higher delivery velocity that meets the desired real-time guarantee. 3) Initiative drop control module decides whether the packet to be drop or not, in case of power adaptation mechanism cannot find new suitable forwarder. Even thought all the components of proposed protocol is same as that of the earlier mentioned THVR protocol, but the implemented methodologies are different. Performance analysis showed that the PATH outperforms THVR in terms of packet dropping and energy balance throughout the network that leads to the prolonged network lifetime.

CBRR: [28] Chao Huang et al proposed a Contention-based Beaconless Real-time Routing protocol (CBRR) aims at meeting the end-to-end real time communication guarantee along with the less energy consumption. In the proposed protocol, a novel contention based beaconless data-forwarding policy is used that eliminates the limitations of beacon-based schemes. The contention-based scheme is a reactive scheme, because each node can select its optimal next forwarder node in online without having any prior information about their neighbors. I.e. when a node has a data to transmit, first, it broadcasts a contention message to all its neighbors and the one offer a shortest wait delay is select as the most suitable next hop forwarder. The key features of CBRR include; CBRR gets the information about the neighbors in neighborhood table by using contention messages rather than beacons. CBRR can also collect the information from the two-hop information and maintains the two-hop neighborhood table that can be helpful further meeting the real time requirements in two-hop range. Based on the one-hop neighborhood table and the two-hop neighborhood table two versions of CBRR are proposed namely; CBRR one-hop protocol, CBRR two-hop protocol. CBRR-one hop protocol consists of five components namely: unicast forwarding policy, contention forwarding policy, contention function with wait delay, delay estimation and one-hop neighborhood table. One-hop neighborhood table of a node maintains the information about all its neighbors and contains the field like neighbor ID, neighbor position, one-hop delay. Unicast forwarding policy uses the speed constraint to determine whether the data packet is forwarded by direct unicast or by invoking contention policy. Contention forwarding policy first uses delay constraint to determine contention candidates and then by using ERTS (Extended Request To Send), ECTS (Extended Clear To Send), DATA, ACK handshake it selects a new next-hop forwarder. In contention forwarding policy, the current node first broadcasts an ERTS packet to all its neighbor and wait for an ECTS packet. When it receives an ECTS from node with least wait delay, the current node transmit the DATA and waits for the ACK from the next hop forwarder node. When it receives the ACK, the current node updates its neighborhood table. The key factor of this contention based beaconless scheme is contention function, which determines the wait delay of each contention candidate. The proposed contention function considers the combination of factors like; progress of data packet towards the sink, the remaining energy of the node and the number of packets waiting in the output queue. The delay estimation module is responsible to calculate the one-hop delay between two neighbors. CBRR –Two-hop protocol is an extension of CBRR-one- hop protocol that uses the advantages of two hop neighborhood information to further meet the real-time requirements in the two-hop range. Simulation results showed that CBRR performs well in terms of delivery ratio, energy consumption and end-to-end delay.

OMLRP: [29] On-demand Multi-hop Lookahead Real-time routing protocol (OMLRP) is a novel multi-hop information based real-time routing protocol for a wireless sensor networks. OMLRP only carries out the multi-hop look ahead when a real-time data delivery is needed otherwise, for non real-time data; it follows conventional single-hop information like that in SPEED. In order to restrict the lookahead mechanism only around the forwarding path it considers an elliptical region that is calculated based on the location information of source and the destination at any sensor node. This novel on-demand multi-hop lookahead mechanism involves three phases namely: Multi-hop Lookahead Trigger, Lookahead Message Exchange and Multi-hop management. In Multi-hop Lookahead Trigger, when each node has a data to send, for the very first time it sends data in conventional single hop by hop method to the next forwarder node that meets the desired speed until the data has reached to the destination. During this first data packet transmission along the delivery path, each node in this forward path triggers the multi-hop lookahead. I.e. In strict sense, multi-hop lookahead is started in gradual process by using hop-by-hop forwarding of first data packet. In look ahead message exchange phase, OMLRP uses a lookahead message that contains the parameters like source and destination location, Khop, Hellipse. Khop indicates the hop-limited value that specifies the number of nodes location and transmission speed has to be maintained for multi-hop lookahead mechanism. Hellipse is the semi-minor axis of the elliptical region. The parameters source, destination location and Hellipse are used to restrict area of multi-hop look ahead. If any sensor node receives a lookahead message, first it checks whether it falls inside the elliptical region or not by using the parameters inside the lookahead message. If the sensor node is not located in elliptical region then it does not reply, otherwise, the sensor node responds to the lookahead message by using an acknowledge message. The acknowledge message carries location of a present node at the same time location and transmission information of the neighbor nodes of that sensor node. Like this, by using the lookahead messages, acknowledgement messages it collects the one-hop, two-hop, three-hop … neighbors information until the specified Khop count reached. OMLRP provides the optimal paths form source to the destination that guarantees the real time transmission by using the multi-hop information from the proposed novel multi-hop lookahead mechanism. OMLRP provides the least deadline miss ratio and void area avoidance by means of this multi-hop lookahead mechanism. Simulation results showed that the proposed protocol succeed in providing lower deadline miss ratio, less total communication costs, and the prolonged network life time.

QEMPAR: [30] is an acronym of Qos and Energy Aware Multi-Path Routing Algorithm for Real-time applications in wireless sensor networks which is a novel multi-path routing algorithm that addresses both QoS in terms of timeliness and energy efficiency for real-time applications of wireless sensor networks. Routing of real-time data packets from source to destination will undergo through three phases namely; path discovery mechanism, link suitability, paths assortment phase. During phase discovery phase each node collects the information from their immediate neighbors by exchanging beacons and maintain the same in neighborhood table. This collected information in every node helps in finding the link suitability for its neighbors. In order to select the optimal next forwarder node among the set of neighborhood nodes, a node uses the link suitability during the path discovery phase. The proposed link suitability function considers the parameters like; Probability of Packet Sending (PPS), Average Probability of Packet Receiving (APPR) and Interference of a link between the two nodes. In path assortment phase, after discovery and construction of paths, the real time data packet is divided in small chunks and assigns with a sequence number to each of the small data packet. Then Source node divides all the constructed paths into several classes based on the hop-counts of individual path between source node and destination. Then source node sends each of the tiny packets through separate paths where the tiny packet having the sequence number as „1‟ is sends through the path having the least hop count. Likewise, the packet of increasing sequence number sends through the path having increasing hop count. This type of path assortment helps in fast sending and consequently reducing end-to-end delay which aid in meeting real time communication guarantee. Simulation results showed that the proposed protocol performs well in optimizing end- to-end delay and utilizes less energy consumption in delivering real-time packets.

3R-protocol: [31**]** is a Reliable, Real-Time Routing protocol (3R) for highly time-constrained wireless sensor and actuator networks (WSAN). The main idea of this protocol is to send copies of data packets in different parallel routes to its destination that eventually reduce the probability of sequential packet losses that is there in single route transmission. This in turn significantly reduces the transmission delay of real-time data packets communication from source to destination. A Routing metric that balances between timing constraints against reliability requirements and a routing algorithm that utilizes this metric are considered as the important parts of the proposed routing protocol. The proposed routing metric is based on the parallel multi-path transmissions, which reduce message transmission latencies. This reduced transmission latency is achieved by sending packets at the same time through several disjoint routes. Disjoint routes are those routes have no common nodes except the destination. In the proposed protocol to satisfy the timing and routing constraints, routing metric has to choose noninterfering disjoint routes by applying Dijkstra's shortest path algorithm. In order to create the disjoint routes according to the routing metric, Dijkstra's shortest-path algorithm is being used. After running the Dijkstra's shortest path algorithm each node inside the network is assigned with the weight that is equal to the number of estimated worst-case transmissions regarding to the requested reliability. As number of transmissions can be expressed as timing constraints, therefore the weight of the node can be equivalent to the worst-case transmission time regarding packet reaching probability. So, the one route out of these disjoint set of routes that satisfies the timing constraints will be choose for real time packet forwarding. The proposed MAC layer is tightly coupled with the routing metric that mitigates problems of transmission overhead due to the multipath routing. Performance results showed that the proposed 3R-protocol assures the reliable, real-time data transmission by means of reduced transmission delays**.**

RACE: [32] Hossein et al proposed a novel protocol for real-time applications in wireless sensor networks, named as RACE. The proposed protocol is a real-time power aware protocol, which is not limited to a specific application, and is adjustable to be delay or power aware or both. The key design aim of the proposed algorithm is to support a soft real-time communication service through the path with minimum delay across the sensor network, so that the end-to-end delay is proportional to congestion of nodes between source and destination. It satisfies the design objectives that includes; stateless architecture, supporting soft real time communication, QoS routing and congestion management, load balancing and localized behavior. It is a complete stateless architecture where it does not maintain complete network states in the form of routing table. It maintains only neighborhood table that contains information only regarding the immediate neighbors that in turn reduces memory requirement. It manages the congestion situations very effectively by re-routing packets around the large delay links along with less overhead. The proposed protocol effectively balances the load by using non-deterministic forwarding to balance each flow among multiple concurrent paths. It is a pure localized algorithm where any action invoked by node does not affect the system as a whole. The proposed algorithm has two coefficients α and β that specify the importance of power consumption and real-timeliness. In order to find the path with minimum delay between source and destination, authors used the Loop-free Bellman-Ford algorithm that is very similar to Dijkstra's algorithm. Each node has a routing table contains four fields namely ID, Cost of Delay, Cost of Energy, Total Cost. Cost of delay is termed as the smallest amount of time that is necessary to deliver a packet from a node to sink. Cost of Energy is termed as the amount of time that each of neighbors of a node has enough energy to transfer a data packet to the sink. Total cost is the function of α, β, Cost of Delay, Cost of Energy as follows; *Total Cost*= ({α x (1/(*Cost of Energy*)}+{β x *Cost of Delay*}). Where α, β are set by application that specify the power aware and real time requirement. If α increases, β will decrease and if β rises, α will go smaller. Therefore, in order to select a next forwarder, a node uses the Total cost amount in its routing table and selects a next hop forwarder node having least Total cost. This load and energy consumption balance leads to the prolonged lifetime. It uses a prioritized MAC same as that of RAP for global prioritization of packets in meeting the real time requirements. Performance analysis showed that the proposed protocol outperforms SPEED, RAP in terms of average end-to-end delay and the deadline miss ratio.

A summary of above-mentioned literature of real-time routing protocols is given in Table 1.

Table 1. A Summary of the real-time routing protocols in WSN.

S.No.	Routing protocol	RT-type	Energy Efficiency	Reliability
1.	SPEED	SRT	Low	N/A
2.	RAP	SRT	Low	N/A
3.	Akkaya et al	SRT	High	Moderate
4.	MM-SPEED	SRT	Low	Good
5.	Mahapatra et al	SRT	Good	Good
6.	Pothuri et al	SRT	Good	N/A
7.	Ergen et al	HRT	Good	N/A
8.	RPAR	SRT	Good	N/A
9.	FT-SPEED	SRT	Low	Good
10.	EDRP	SRT	High	N/A
11.	ARP	SRT	Good	Good
12.	Khalid et al	SRT	High	N/A
13.	Yuan.L et al	SRT	High	N/A
14.	Min Chen et al	SRT	Moderate	Moderate
15.	RTLD	SRT	Good	High
16.	THVR	SRT	Low	Good
17.	Ling Ming He et al	SRT	Good	Good
18.	DMRF	SRT	Good	High
19.	PATH	SRT	High	Good
20.	CBRR	SRT	Good	N/A
21.	OMLRP	SRT	Low	High
22.	QEMPAR	SRT	Good	Good
23.	3R-Protocol.	SRT	Moderate	Good
24.	RACE	SRT	High	Good

4. Challenges And Open Research Issues In Real Time Routing In WSN

Real time routing is an exciting, but very challenging task in WSN. In papers [6], [7] authors pointed out various challenges and open research issues like; RT and energy aware, RT and multiple QoS (reliability, band width efficient…etc) requirements, RT capability for multiple sources and multiple sinks, cross layer design to meet the HRT requirements and RT support for the special application scenarios. From the above literature, it is observed that the issues like energy and QoS along with RT are well addressed by good number of protocols. Whereas, the issues like RT capability for mobile nodes, RT capability for multiple sources and multiple sinks, and the cross layer design that meets the requirement of HRT are still remains as gap areas of research in real time routing domain.

5. SUMMARY

Hence, a real-time routing is playing an important role n providing real time communication in case of WSNs operating in the real world. Because of having an implicit or explicit time constraints, non deterministic nature of links, and resource constrained environment of WSN, real time routing is quite exciting and at the same time extremely challenging to meet the real-time demands. In this paper, we present a review of real time protocols along with their key features. Finally, we present a comparative summary of the literature and the present gap areas of research in real time routing in WSN.

REFERENCES

[1] I.F. Akyildiz et al, W.Su, Y.Sankarasubramaniam, E.Cayirci "Wireless sensor networks: a survey", Computer Networks, Vol. 38, pp. 393- 422, March 2002

[2] K.Akkaya, M younis "A survey on routing protocols for wireless sensor networks" Ad Hoc Networks 3 (2005), pp 325-345, 2005.

[3] J.N. Al-Karaki and A.E. Kamal (2004). "Routing Techniques in Wireless Sensor Networks: a Survey," IEEE Wireless Communications, vol. 11, no. 6, pages 6-28, 2004.

[4] Stankovic J, Abdelzaher T and Lu C et al., "Real-time communication and coordination in embedded sensor networks," in the proceedings of IEEE 91(7) [C], 1002-1022.

[5] M.Soyturk, H.Cicibas and O.Unal, "Real-Time Data Acquisition in Wireless Sensor Networks", from the book, " Data warehousing", InTech open access publisher, 2010.

[6] Li Y, Chen C ,Song Y and Wang Z , "Real-time QoS support in wireless sensor networks: a survey," in the Proceedings of 7th IFAC Int Conf on Fieldbuses & Networks in Industrial & Embedded Systems (FET"07) [C], Toulouse, France, Nov 2007.

[7] A.Zhan, T.Xu, G.Chen, B.Ye and S.Lu, "A Survey on Real-time Routing Protocols for Wireless Sensor Networks", in Proc. of The 2nd China Wireless Sensor Network Conference (CWSN-2008), Chongqing, China, October 13-14, 2008.

[8] S.Bansal, D.Juneja, S.Mukherjee " An analysis of real-time routing protocols for the wireless sensor networks" in International journal of Engineering Science and Technology (IJEST), Vol.3, no.3, pp 1797-1801, march 2011.

[9] C. Lu, B. Blum, T. Abdelzaher, J. Stankovic, and T. He." RAP: A Real- Time Communication Architecture for Large-Scale Wireless Sensor Networks," In IEEE Real-time Applications Symposium, 2002.

[10] T. He, J. Stankovic, C. Lu, and T. Abdelzaher." SPEED: A stateless protocol for real-time communication in sensor networks," In ICDCS, 2003.

[11] K.Akkaya, M.Younis. "Energy-aware delay-constrained routing in wireless sensor networks". International Journal o f Communication Systems, 2004: pp 663-687.

[12] E.Felembane, C. Lee and E. Ekicie, R.Boder, S.Vural "MMSPEED: Multipath multi-SPEED protocol for QoS guarantee of reliability and timeliness inwireless sensor networks," IEEE Transactions on Mobile Computing [J], 5(6), pp. 738-754, 2006

[13] A.mahapatra, K.Anand, D.P.Agrawal. "QoS and energy aware routing for real-time traffic in wireless sensor networks". In Elsevier, computer communications 29(2006), pp 437-445.

[14] Pothuri P, Sarangan V and Thomas J, "Delay-constrained, energy-efficient routing in wireless sensor networks through topology control," in the Proceedings of 2nd IEEE International Conference on Networking [C], Sensing and Control, April 2006.

[15] Chipara O, He Z and Xing G et al., "Real-time Power-Aware Routing in Sensor Networks," in the Proceedings of the 14th IEEE International Workshop on Quality of Service (IWQoS 2006) [C], New Haven, CT, June 2006.

[16] Lei, Z.; Kan, B.Q.; Xu, Y.J.; Li, X.W "FT-SPEED: A fault-tolerant, real-time routing protocol for wireless sensor networks". In Proceedings of 2007 International Conference on Wireless Communications, Networking and Mobile Computing, Shanghai, China,pp. 2531–2534, 2007.

[17] A.Pourkabirian, A.T.Haghighat,." Energy-aware, delay-constrained routing in wireless sensor networks through genetic algorithm", in Software, Telecommunications and Computer Networks, 2007. SoftCOM 2007, pp 1-5, 2007.

[18] H.Peng, Z.Xi, L.Ying, C. Xun, G. Chuanshan (2007), " An Adaptive Real-Time Routing Scheme for wireless sensor networks", In the proceedings of 21st International Conference on Advanced Information Networking and Applications Workshops (AINAW'07) , IEEE(2007).

[19] Khalid Z, Ahmed G and Khan N, "A Real-time Energy-aware Routing Strategy for Wireless Sensor Networks," in the Proceedings of Asia-Pacific Conference on Communications [C], p.381-384, 2007.

[20] L.Yaun, W. Cheng, X.Du, " An energy-efficient real-time routing protocol for the sensor networks", In Elsevier, Computer communications[j] 30 , pp 2274-2283, 2007.

[21] Chen M, Leung V and Mao S et al., "Directional geographical routing for real-time video communications in wireless sensor networks", In Elsevier, Computer Communication [J], 30 (2007), p.3368-3383, 2007.

[22] A.Ali Ahmed, N. Fisal, " A real-time routing protocol with load distribution in wireless sensor networks". In Elsevier, computer communications31[j] , pp 3190-3203, 2008.

[23] J.Kim, B.Ravindran, "Oppurtunistic Real-time Routing in Multi-Hop Wireless Sensor Networks", in the proceedings of SAC'09 ,march 2009.

[24] Y. Li, C.S.Chen. "Enhancing Real-Time delivery in wireless sensor Networks with Two-Hop information". In IEEE Transactions on Industrial Informatics, Vol.5.No.2, May 2009.

[25] Li-Ming He, " A Novel Real-Time routing protocol for wireless sensor networks", In the proceedings of 10th ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and parallel/ Distributed Computing, 2009.

[26] G.Wu , C. Lin , F.Xia , L.Yao , H. Zhang, and B. Liu "Dynamical Jumping Real-Time Fault-Tolerant Routing Protocolfor Wireless Sensor Networks", Sensor 2010 .

[27] P. Rezayat, M. Mahdavi, M.Ghasemzadeh, M.Agha Sarram, "A Novel Real-Time Power Aware RoutingProtocol in Wireless Sensor Networks," IJCSNS International Journal of Computer Science and Network Security, VOL.10 No.4,April 2010.

[28] C.Huang, G.Wang, "Contention- Based Beaconless Real-Time Routing Protocol for Wireless Sensor Networks" . In Scientific Research, Wireless sensor networks, 2, pp 528-537, july 2010.

[29] J.Jung S Park, . Lee, S.Oh, S.Kim, "OMLRP: Multi-hop information based Real-Time Routing Protocol in Wireless Sensor Networks". In proceedings of Wireless Communications and Networking Conference (WCNC), 2010 IEEE. pp 1-6, apirl 2010.

[30] S.R. Heikalabad H.Rasouli, F.Nematy, N.Rahman " QEMPAR: Qos and Energy Aware Multi-Path Routing Algorithm for the Real-Time Applications in Wireless Sensor Networks". In International Journal of computer science Issues, Vol.8, Issue 1, January 2011.

[31] M.krogmann, M. Heidrich, D Bichler, D. Barisic, G.Stromberg" Reliable, Real-time routing in wireless sensor and actuator networks" , in International Scholarly Research Network(ISRN) communications and Networking , Volume 2011.

[32] S.M. Hossein Jalilolghadr, M. Sabaei, "Proposed a new algorithm for real-time applications in routing of wireless sensor networks", in the proceedings of 2011 International conference on management and artificial intelligence (IPEDR), Vol.6 (2011), IACSIT press 2011

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