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A Survey of QoS based on Real time and Reliable Routing Protocols for Wireless Sensor Networks

Anuj Kumar Jain[1*], Sandip Goel[2], Devendra Prasad[3]

[1]PhD Scholar, CSE Department, Maharishi Markandeshwar (Deemed to be University), Mullana, Haryana, India
[2] Prof. & Head, CSE Department, Maharishi Markandeshwar (Deemed to be University), Mullana, Haryana, India
[3] Prof. CSE Department, Chandigarh Group of Colleges, Landran, Punjab, India

Corresponding Author: jainanuj143@gmail.com, Tel.: +91-80599-30871

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***Abstract*–**Contemporary development in wireless sensor networks has haltered the expeditious advances in real-time applications. Numerous routing protocols were proposed for these applications however design issue is real-time guarantee. In this paper, the futuristic in WSN routing protocols is surveyed whilst emphasizing on merits and performance issues. The paper provides a classification of real-time routing protocols and highlights another major issue in this direction, i.e. reliability along with other research issues.

***Keywords*—**Wireless Sensor Networks, Reliable transport protocols, Real Time Routing.

I. INTRODUCTION

Current developments in wireless communications and embedded systems have introduced wireless sensor networks (WSNs), comprising of less power consuming, low-cost, multifunctional sensor nodes (SNs) that are small in size and communicate over short distances [1]. A Wireless Sensor Network (WSN) encompasses of a huge number of SNs which are densely & randomly deployed in the area being observed. SNs sense data and transport it to complex processing nodes or more high power nodes called the sink or base station (BS). User can access them via Internet or directly with actuators which perform actions in response. In emerging applications, the need of low latency transmission is becoming more important despite the energy efficiency is primacy concern in WSNs. Stale information causes negative effects to the system control and surveillance.

Fire monitoring, intrusion tracking, medical care and structural health diagnosis are the main applications of real time (RT) wireless sensor systems [7]. To initiate on time pursuing actions, The command centre or base station should be reported within a specific time limit by the monitoring system in case of intrusion detection systems.[5]. Different deadlines of data may exist in the same system due to different requirements. For example, delivery of location information of pedestrians has larger update deadlines in comparison to tanks [5] or moving vehicles. Fire monitoring system has several applications of sensor networks. For instance, the information delivery of a sudden temperature rise in a monitored forest area to the sink or command centre should meet end-to-end deadlines with timing constraints. Hence the real time communications or monitoring should be supported in a sensor network protocol resulting in a reduction in the packet deadline miss ratio (the percentage of all packets that missed or lost end-to-end deadlines).

Due to wireless nature, dynamic network topology, low node reliability and limited resources (power, processing and memory) - WSNs differs from the conventional RT systems [15]. So, to maximize lifetime of the network, incubating RT applications (over WSNs) should consider discovering energy efficient path and relaying of data from the sensor nodes to the sink.

In sensor network, RT routing is arduous because of numerous features that are distinctive from wireless ad-hoc networks and modern communication. First, for ordering of data packets received from sensor nodes requires redesigning of global unique addressing scheme. Second, dedicated resource management is required as sensor nodes are more affected in case of energy, storage on-board and the processing capacity. Third, improving RT QoS metrics in WSNs require redesigning of RT routing.

Rest of the paper is organized as follows, Section II contains the system insight and design constraints for wireless sensor networks. Section III contains the routing protocols for real time routing, discusses various QoS metrics for wireless sensor networks & compares various reliable & real time routing protocol. Section IV concludes the survey of routing protocols.

I.SYSTEM INSIGHT AND DESIGN CONSTRAINTS

Every application has different design aim/inhibition and architecture. As RT routing protocol performance is allied to the architectural model so we endeavor to discuss architectural issues and insinuations in this section.

Dynamic and Adaptive Nature: Three crucial components of sensor network are observed events, sink and sensor nodes. Sensor nodes and sink are assumed as stationary by majority of the architectures. The mobility of sensor nodes and the base station/s is supported by some architecture. Designing RT routing for mobile nodes is more arduous. Dynamic or static nature of events depends upon the application the network is used for [28]. A localization/target detection/tracking application, can be an example of dynamic event whereas temperature or environment monitoring can be static events.

Modes of Data Delivery in the Network: The possible modes of data delivery are continuous, event-driven, query-driven or even a hybrid one [28] depending upon the application. Sensor nodes in a continuous mode send data periodically. In event-driven mode, the data transmission is triggered when an event occurs. Similar is the case with query driven model where data transmission occurs when a query is generated by the sink. For few applications Hybrid models can also be used where a combination of these previous three models can be used.

Severity of Real Time: Severity of Real Time can classify a RT system into two types, i.e. hard real-time and soft real-time [7]. In case of hard real-time system, a deterministic end-to-end delay bound is supported. If message arrives after its deadline then it is considered as a failure of the complete system. Whereas in case of soft real-time system a probabilistic data delivery is considered and therefore, delay in service or packet delivery is tolerable.

Quality of Service Metrics- Numerous parameters are there to compare & measure the performance of numerous routing protocols in WSN. Different metrics are Signal to Noise ratio (SNR), Packet Delivery ratio, Average end-to-end delay, Bit error rate, Energy consumed, Throughput, Network lifetime.

Performance of the WSN routing protocol is given in table 1.

II. PROTOCOLS FOR REAL TIME ROUTING

In previous literature, a number of protocols have been proposed that are designed keeping in mind the QoS for wireless adhoc networks [7], [9], [11]. Most of them are based on terminal route discovery and formation with a resource conservation, which makes them impractical for dynamic and large scale sensor networks. Currently there are lot of studies that focus either reliability or real time delivery of data in sensor networks. RAP [5], SPEED [3] are few of them.

Table 1: QoS Metrics in WSN routing protocols

Sr. No.	**Quality of Service Metrics**	**Description**
1.	Signal-to-Noise Ratio (SNR) (expressed in db)	Ratio of desired signal strength to background noise strength.
2.	Packet Delivery Ratio (expressed in number of packets)	Ratio of entire number of delivered packets successfully received by the sink node to the number of packets sent by all sensor nodes[36].
3.	Bit Error Rate (expressed in %)	Number of bit errors divided by total number of transferred bits in a specified time interval [37].
4.	Average end-to-end delay	Time taken by a data packet to be transmitted from source to destination across network [36].
5.	Energy Consumed (expressed in KJ)	Rate at which energy is dissolute within a specific time period by a sensor node[36].
6.	Average Throughput (expressed in bits per second i.e. bps)	Average number of data packets successfully received in per unit time by a sink node[36].
7.	Network Lifetime (expressed in minutes)	Time elapsed until the deployed nodes die.

RAP [5] provides service differentiation in the timeliness domain by classifying velocity-monotonic classification of packets. Based on packet's deadline and destination, its demanded velocity is calculated and priority is decided in the order of velocity-monotonic way such that a packet with high velocity could be reached earlier than one with a low velocity. However, it is best-effort service differentiation without any guarantee in the sense of end-to-end delivery. Implicit EDF [8] can provide hard real-time guarantee based on decentralized EDF packet scheduling. However, it works only if most of the traffic is periodic and all periods are known a priori, which is not the case for most number of applications of sensor network. Also, it is not adaptive to dynamics of sensor networks.

RPAR: Real-time Power-Aware Routing protocol (RPAR) [13] attempts to provide real-time communication and energy efficiency in WSNs. RPAR dynamically adapts transmission power while taking routing decisions as per the deadlines for packet delivery. RPAR can adjust power of communication from time to time. Unlike MMSPEED it does not require to define different delivery speeds. It also uses an on-demand mechanism for neighbor-hood management which reduces the energy dissipation while SPEED and MMSPEED exchange beacons periodically and thus waste a lot of energy in the process. This scheme is invoked if no choice is valuable in the neighbor table to forward a packet. Simulations results depict that a large amount of energy is saved by this neighborhood management mechanism. It not only saves energy but also provides a considerable amount of reliability of real time delivery of packet. Only problem is, the time taken in neighbor discovery process. Given the fact that there is always a tradeoff between the real time delivery of packets and reliable delivery of packets this combination of RPAR and neighborhood management scheme is a considerable option for any real time application with a desire of reliability.

Energy-Aware QoS Routing Protocol: Energy-aware Quality of Service routing protocol is presented by Akkaya and Younis [17] which can meet end-to-end delay requirement & we can discover the path which is energy-efficient. Suggested protocol in [18] discovers delay-constrained and a least cost path while considering nodes' communication parameters, transmission energy and energy reserve for real time data. Additionally, while balancing the service rate at sensor nodes for real-time and non-real-time data, throughput is maximized for non-real-time data. A model for class-based queuing is implemented to give best effort and real-time traffic.
Classifier checks incoming packet type at each node and separate priority queues are assigned to reroute real-time traffic and non-real-time traffic. Multiple priorities are not supported for the real-time traffic is the drawback of this approach.

SPEED: SPEED, a soft real time communication Quality of Service routing protocol that provides end-to-end guarantees for sensor networks, is presented in [3]. The protocol finds path by using geographic forwarding and requires the every node to maintain information about its neighbors. In addition, SPEED endeavors to maintain a certain delivery speed for every packet in the network. It helps in estimating the end to end packet delay by dividing the distance between the sink and the speed of the packet. SPEED also helps in efficiently handling voids and in congestion avoidance with minimal control overhead.

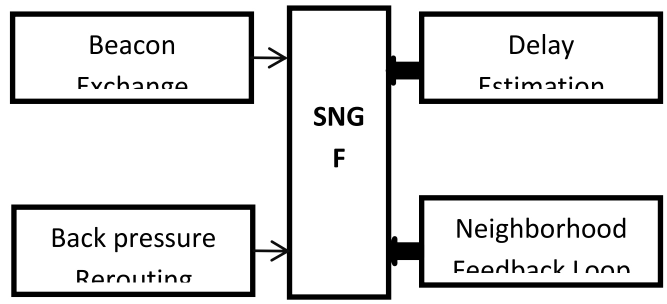

Fig. 3 Routing components of SPEED [3].

SPEED uses Stateless Geographic Non-Deterministic forwarding (SNFG) routing module and at the network layer toils accompanied by other four modules, as shown in Fig. 3 [3]. The information about nodes and location of nodes is collected using beacon exchange mechanism. Elapsed time between transmitted data packet and ACK received from the neighbor as a response, is used for estimating delay at each node. SNGF chooses the speed satisfying nodes by observing delay values and nodes' relay ratio is examined If a right node cannot be found. Providing relay ratio is the responsibility of Neighborhood Feedback Loop (NFL) module, which can be measured by inspecting the miss ratios of the neighbors of a node (nodes which did not cater the desired speed) and is fed to the SNGF module. Packet is likely to be dropped wherever the relay ratio may be less than a arbitrary produced number between 0 and 1. Finally, to prevent voids and to eliminate congestion by sending messages back to the source nodes to pursue new routes, the back pressure-rerouting module is used when a node fails to find a next hop node.

SPEED protocol observes better performance in terms of end-to-end delay and miss ratio when compared to Ad-hoc On-demand vector routing (AODV) [11] and Dynamic Source Routing (DSR) [10]. As control packet overhead is less due to the simplicity of the routing algorithm and even traffic distribution is there, the total transmission energy will be less and load balancing is achieved through the network. SPEED does not consider any further energy metric in its routing protocol, and it is one of the drawback. Therefore, there is a need for comparing it to a energy aware routing protocol for more rational understanding of SPEED's energy consumption. Moreover, the packet can be forwarded by every forwarding node at a speed less than or equal to the maximum achievable speed because prioritization scheme is not available in proposed protocol. Even if the network can support forwarding the packet on a higher speed, still it is not feasible to forward a packet at a higher speed. The idea of per-flow booking appears to be non-scalable in a WSN due to the highly dynamic link and route characteristics; hence for large WSNs, SPEED might not be scalable. To manage the void situation produced by probability of high sensor failure, FT-SPEED [21] as an extension of SPEED is proposed. In FT-SPEED, to halt the packets arriving the void from different routing path, a scheme called void announce is designed. To ensure the packets delivery, a void detour scheme has been introduced to route the packets over both sides of a void.

MMSPEED: An extension of SPEED is called Multi-path and Multi-SPEED Routing Protocol (MMSPEED) [6]. MMSPEED provides a probabilistic Quality of Service guarantee. Timeliness and Reliability are the two domains where Quality of Service is provisioned. Numerous QoS degrees in the domain of timeliness is accessible by imparting option of numerous network-wide packet transportation speed guarantees. Omitting global network information, the localized terrestrial packet forwarding scheme is employed which is enhanced with dynamic payoff. Local decision inaccuracies are compensated by the scheme as a packet transits towards its destination.

The speed level can be increased by intermediate nodes if intermediate nodes find out that on the current speed the packet may lapse the delay deadline.

At the MAC layer, MMSPEED needs the aid of IEEE 802.11e along with its constitutional Differentiated Inter-Frame Spacing (DIFS) based prioritization mechanism. Every speed level is outlined upon a MAC layer priority class. To support reliability of service & to control number of delivery paths, probabilistic multi-path forwarding is used based on the obligatory end-to-end arriving probability. By employing the packet loss rate, every node in the network computes the feasible forwarding probability of every neighbor. To achieve desired reliability level, every node in the network can send numerous duplicated packets to a cluster of chosen neighbors. However, Energy consumption is a common inadequacy in SPEED and MMSPEED.

Yuan et al.: [34] Based on SPEED, it suggests a routing protocol for wireless sensor networks which is real time energy-efficient. Effective Transmission (ET) concept fortifies that source node should be farther from forwarding candidates and forwarding nodes should be nearer to the sink. It improves transmission efficiency by limiting candidate’s node area. They differentiate end-to-end delay of whole path guarantee into Constrained Equivalent Delay (CED). According to value of CED, next forwarding node is decided independently by each intermediate node. Sum of entire links delay is not required to be calculated. So, route discovery process can be simplified and overhead can be greatly reduced.

Z. Khalid et al.: [35] Established on Logical Network Abridgment (LNA), for WSN they suggest a routing strategy which is real-time energy-aware. Innate health of entire network can be described using LNA procedure. Energy and time awareness cost functions are considered by the protocol. Lot of research for recognizing the cost functions and choosing the parameter values is required there. Routing protocol for accommodating gateway mobility is their future plan.

Real time routing protocols comparison: A detailed summary of WSN real time routing protocols is given in the table 2.

Table 2: Summary of real time WSN routing protocols

Protocol	Routing Type	Energy Efficiency	Scalability Status	Link Reliability
Akkaya and Younis	Soft Real Time	High	Low	Moderate
RAP	Soft Real Time	N/A	Good	N/A
RPAR	Soft Real Time	High	Good	High
SPEED	Soft Real Time	N/A	Good	N/A
MMSPEED	Soft Real Time	N/A	Good	High
Z. Khalid et al.	Soft Real Time	High	Moderate	N/A
Yuan et al.	Soft Real Time	High	Good	N/A

III. CONCLUSION

Research on real time routing protocols in WSN has been a compelling area. Providing real time QoS using routing protocols in WSN has been the common objective. In our paper, numerous WSN routing protocols & their performance issues and advantages & disadvantages have been discussed. Besides, numerous routing protocols are scalable, energy efficient & reliable, still there are many challenges in real time QoS support which needs to be addressed. We are leaving them for future research.

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