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Multipath Routing metrics and QoS in Wireless Sensor Networks: Survey and Research Challenges

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Abstract— Multipath routing is an efficient technique to route data in wireless sensor networks because it provides reliability, security, load balancing, which are critical in resource constrained systems such as WSNs. A wireless sensor network is a large collection of sensor nodes with limited power supply and constrained computational capability. Nowadays, multipath routing approach is widely used in wireless sensor networks to improve network performance through efficient utilization of available network resources. Accordingly, the main aim of this survey is to present the concept of the multipath routing approach and its fundamental challenges, as well as the basic motivations for utilizing this technique in wireless sensor networks. This paper compares and summarizes the state-of-the-art multipath routing techniques from the network application point of view. Finally, we identify open issues for further research in the development of multipath routing protocols for wireless sensor networks. In addition a summary of design goals, challenges and evaluation metrics for multipath routing protocols in resource constrained systems is also provided.

Keywords— wireless sensor networks; multipath routing; load distribution; energy efficiency; reliability; QoS.

I. INTRODUCTION

A wireless sensor network (wsn) consists of a large number of light-weight sensor nodes having limited battery life, computational capabilities, storage, and bandwidth. These low-cost sensor nodes can be deployed either randomly by dropping from an airplane or precisely using manual deployment. These sensor nodes sense a change in the environmental or a physical quantity and transmit this data to the base station, also referred to as a sink node. The sink node is usually a powerful machine like a Laptop or a Desktop [1, 2].

In the past decade, multipath routing approach has been widely utilized for different network management purposes such as improving data transmission reliability, providing fault-tolerant routing, congestion control and Quality of Service (QoS) support in traditional wired and wireless networks. However, the unique features of wireless sensor networks (e.g., constrained power supply, limited computational capability, and low-memory capacity) and the characteristics of short-range radio communications (e.g., fading and interference [3,4]) introduce new challenges that should be addressed in the design of multipath routing protocols. Therefore, the current multipath routing protocols which have been proposed for traditional wireless networks such as ad hoc networks cannot be used directly in low-power sensor networks [5]. Over the past years, this problem has motivated the research community of wireless sensor networks to develop multipath routing protocols which are important for sensor networks. There are numerous research papers surveying proposed routing protocols for wireless sensor networks. These surveys illustrate and analyse the general routing tactics proposed for sensor networks. On the other hand, none of these literatures has presented a comprehensive classification on the presented multipath routing protocols for wireless sensor networks based on energy aware, fault tolerance and QoS based multipath routing. The authors in [6] have presented routing challenges and design issues in wireless sensor networks. They categorize all the presented routing tactics based on the network structure and protocol operation. In addition, the authors [6] have also presented a short overview on the existing fault-tolerant routing protocols in wireless sensor networks and grouped these protocols into retransmission-based and replication- based protocols. Furthermore, [7, 8] categorize the presented multipath routing protocols in ad hoc networks based on the main criterion used in their design. Moreover, [9] have surveyed multipath based Infrastructure, non-Infrastructure and coding multipath routing. Thus, the primary stimulus of accomplishing this research was the lack of a comprehensive survey on the proposed multipath routing protocols for wireless sensor networks based on energy aware, fault tolerance and QoS aware multipath routing. To the best of my knowledge, this paper attempts to categorize and investigate the operation of routing sensor network and also it provides a comprehensive review of multipath routing protocols with highlighting on their advantages and disadvantages of the presented multipath routing protocols in sensor networks.

II. GENESIS OF WIRELESS SENSOR NETWORK

Wireless sensor network is made of single nodes which have the capability to interact within a specific geographical area through the sensing of or by controlling the physical boundaries through the collaboration of sensor nodes and wireless connection to enable transmission of information from nodes to the base station [10]. However Smart Dust at DARPA (Defence Advanced Research Projects Agency of USA) defined WSN as: "A wireless sensor network is a deployment of huge numbers of small, low-cost, self- powered devices that can sense, compute, interact and communicate with other devices in order to gather local information to make global decisions about the physical environment" [11, 12]. The evolution of WSN development begun with the United States of America (USA) during the period of the Second World War with the then Soviet Union which is now Russia. The USA positioned acoustic sensor network at a tactical spot at the bottom of the sea floor with the intention of tracking Soviet Union submarines. The acoustic sensor network application at that time were known as Sound Surveillance System (SOSUS), and it was wired network instead of the current wireless sensor network so the challenges of energy and bandwidth limitations are less minimal [13]. Major research into innovative and advanced sensor networks was initiated by DARPA by USA with the introduction Distributed Sensor Networks (DSN) project in 1980. The acoustic sensor network comprises of transmission, processing schemes, algorithms, routing and distributed software systems. Modernization has also led to rapid advancement of sensor networks recently with the building of small and inexpensive micro-electro-mechanical systems (MEMS). Therefore, the project developed by DARPA contributed dynamic ad hoc network environments and wireless sensor networks in recent times.

III. MODEL OF WIRELESS SENSOR NETWORK

Wireless sensor network has known operational constraints such as resource limitations, node or link prone to failures, nodes densely deployed and the numbers of sensor nodes are so numerous when compared to ad hoc networks. The topology of sensor network has changed over the years, and new technology evolves. The following illustrate the key components of sensor networks: [12, 14]

Sensor Field: A sensor field is vicinity where the nodes can be positioned.
Sensor Nodes: Sensors nodes are the heart of the network. It is the responsibility of the sensor nodes to gather information and transmit to the sink or base station; it is engineered for the network.
Sink: Sink receives data from various nodes, and then process and stored all the data collected from the nodes. Message correspondences between nodes are diminished because of the sink thereby decreasing energy conditions of the entire network.

Task Manager: The tasks Manger acts as a gateway to other networks. The base station also called the centralized control room for data extraction, spread information back and forth to the networks, data processing and storage centre with user access controls. See the figure 1 below for a description; [10].

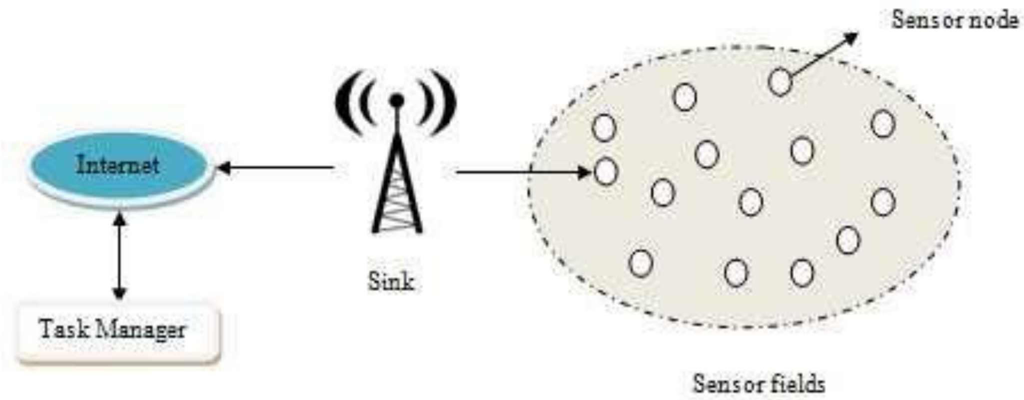

Figure 1: Wireless Sensor Networks Model And Architecture

Data is streamed to these workstations either via the internet, wireless channels, satellite etc. Sensor networks deployed in a specific geographical area does construct a wireless multi-hop network, and the sensor nodes apply wireless medium for transmission namely infrared, radio, Bluetooth during communication. The figure 1 above is the general view of sensor network made by task manager, internet, base station and sensor fields (geographical area deployed).Wireless sensor networks (WSNs) generally consist of one or more sinks (or base stations) and perhaps tens or thousands of sensor nodes scattered in a physical space. With integration of information sensing, computation, and wireless communication, the sensor nodes can sense physical information, process crude information, and report them to the sink. The sink in turn queries the sensor nodes for information. WSNs have several distinctive features:

• *Unique network topology*: Sensor nodes are generally organized in a multihop star-tree topology that is either flat or hierarchical. The sink at the root of the tree is responsible for data collection and relaying to external networks. This topology can be dynamic due to the time-varying link condition and node variation.

• *Diverse applications*: WSNs may be used in different environments supporting diverse applications, from habitat monitoring and target tracking to security surveillance and so on. These applications may be focused on different sensory data and therefore impose different requirements in terms of quality of service (QoS) and reliability.

• *Traffic characteristics*: In WSNs, the primary traffic is in the upstream direction from the sensor nodes to the sink, although the sink may occasionally generate certain downstream traffic for the purposes of query and control. In the upstream this is a many-to-one type of communication. Depending on specific applications, the delivery of upstream traffic may be event-driven, continuous delivery, query-driven delivery, or hybrid delivery.

• *Resource constraints*: Sensor nodes have limited resources, including low computational capability, small memory, low wireless communication bandwidth, and a limited, usually non rechargeable battery.

• *Small message size*: Messages in sensor networks usually have a small size compared with the existing networks. As a result, there is usually no concept of segmentation in most applications in WSNs.

These distinctive features pose new challenges in the design of WSNs that should meet application requirements and operate for the longest possible period of time. Specifically, one needs to carefully cope with such problems as energy conservation, reliability, and QoS. Transport protocols are used to mitigate congestion and reduce packet loss, to provide fairness in bandwidth allocation, and to guarantee end-to-end reliability. However, the traditional transport protocols that are currently used for the Internet (i.e., UDP and TCP) cannot be directly implemented for WSNs [15]. For example, it is well documented that UDP does not provide delivery reliability that is often needed for many sensor applications, nor does it offer flow and congestion control that can lead to packet loss and unnecessary energy consumption. On the other hand, TCP has several other drawbacks:

- Overhead associated with TCP connection establishment might not be justified for data collection in most event-driven
  applications.
- Flow and congestion control mechanisms in TCP can discriminate against sensor node(s) that are far away from the sink, and result in unfair bandwidth allocation and data collections.
- It is well known that TCP has a degraded throughput in wireless systems, especially in situations with a high-packet loss rate because TCP assumes that packet loss is due to congestion and triggers rate reduction whenever packet loss is detected.
- In contrast to hop-by-hop control, end-to-end congestion control in TCP has a tardy response, which means that it requires a longer time to mitigate congestion and in turn leads to higher packet loss when congestion occurs.
- TCP relies on end-to-end retransmission to provide reliable data transport, which consumes more energy and bandwidth than hop-by-hop retransmission.
- TCP guarantees successful transmission of packets, which is not always necessary for event-driven applications in sensor networks.

3.1 The Existing Transport Protocols for WSNS

Several transport protocols have been designed for WSNs (Fig. 1), some of which have addressed congestion or reliability only, while others have examined both. We categorize them into three types:

• Congestion control protocols
• Protocols for reliability
• Protocols considering both congestion control and reliability

Protocols for Congestion Control

Several congestion control protocols have been proposed for upstream convergent traffic in WSNs. They differ in congestion detection, congestion notification, or rate-adjustment mechanisms (Table 1). Among them, Fusion [16] and CODA detect congestion based on queue length at intermediate nodes, while Congestion Control and Fairness (CCF) [17] infer congestion based on packet service time. Priority-based Congestion Control Protocol (PCCP) [18] calculates a congestion degree as the ratio of packet-inter arrival time and packet-service time. Siphon [20] uses the same approach as in CODA to infer congestion; in addition, this approach can detect congestion based on the perceived application fidelity at the sink. CODA uses explicit congestion notification, while others [16,17,18] use implicit congestion notification. In Adaptive Rate Control (ARC) [19], there is no congestion detection or notification; congestion control works as follows: an intermediate node increases its sending rate by a constant as if it overhears successful packet forwarding by its parent node. Otherwise, the intermediate node multiplies its sending rate by a factor b, **n.** where $0 < b < 1$. ARC maintains two independent sets of a and b, respectively, for source traffic and transit traffic in order to guarantee fairness. In contrast, Fusion controls congestion in a stop-and-start non smooth manner. In Fusion, neighboring nodes stop forwarding packets to the congested node immediately when congestion is detected and notified.CODA adjusts the sending rate similarly to AIMD, while CCF and PCCP use an exact rate adjustment algorithm. Compared to CCF, PCCP provides priority-based fairness and overcomes the drawbacks from the use of non work conservative scheduling. However, there is no rate adjustment in Siphon. When congestion occurs, Siphon redirects traffic to virtual sinks (VSs) that, beside the primary low-power mote radio, have another long-rage radio used as a shortcut or "siphon" to mitigate congestion. Trickle [21] uses "polite gossip" to control traffic. In Trickle, each node tries to broadcast a summary of its data periodically. In each period, a node can "politely" suppress its own broadcasting if the number of the same metadata, which this node receives from neighboring nodes, exceeds a threshold. On the other hand, if nodes receive new code or metadata, they can shorten the broadcast period and therefore broadcast the new code sooner. In Trickle, metadata are used to describe the code that sensor nodes use, which is usually smaller in size than the code itself.

Table 1. Existing WSNs' transport protocols

Protocols	Fea tur		
	Congestion detection	Congesti on	Congestion mitigation
STCP [15]	Queue length	Implicit	AIMD-like end-to-end rate adjustment
Fusion [16]	Queue length	Implicit	Stop-and-start hop-by-hop rate adjustment
CODA [22]	Queue length and channel status	Explicit	AIMD-like end-to-end rate adjustment
CCF [17]	Packet service time	Implicit	Exact hop-by-hop rate adjustment
PCCP [18]	Packet interarrival time and packet service time	Implicit	Exact hop-by-hop rate adjustment
ARC [19]	The event if the packets are successfully forwarded or not	Implicit	AIMD-like hop-by-hop rate adjustment
Siphon [20]	Queue length and application fidelity	—	Traffic redirection
Trickle [21]	—	—	Polite gossip

Protocols for Reliability

As shown in Table 2, some transport protocols examine upstream reliability; others, investigate downstream reliability. In the upstream direction, ESRT discusses fidelity of the event stream and only guarantees *event reliability* through end-to-end source rate adjustment. In contrast, Reliable Multi-Segment Transport (RMST) and Reliable Bursty Convergecast (RBC) provide *packet reliability* through hop-by-hop loss recovery. The end-to-end source rate adjustment in ESRT follows two basic rules:

- If the current reliability perceived at the sink exceeds the desired value, ESRT will multiplicatively reduce the source rate.
- Otherwise, the source rate is additively increased if the required reliability is not met, unless there is congestion in the network.

RMST jointly uses selective NACK and timer-driven mechanism for loss detection and notification, while RBC uses a windowless block Acknowledgment with IACK. RBC proposes intranode and internode packet scheduling in order to avoid retransmission-based congestion. In the downstream direction, traffic is multicast one-to-many. The explicit loss detection and notification meets the same problem of control message implosion as that in conventional reliable IP multicast. However, the existing approaches for reliable IP multicast do not consider several distinctive features of WSNs, especially resource constraints and application diversity. Therefore, these are not feasible for WSNs.Both GARUDA and PSFQ use NACK-based loss detection and notification, and local retransmission for loss recovery, but they design different mechanisms to provide scalability.GARUDA constructs a two-tier topology and proposes two stage loss recovery. The two-tier topology consists of two layers, respectively, for core nodes and noncore nodes. The *hop-count* of each core node from the sink is a multiple of three. Then the first-stage loss recovery is used to guarantee that all core nodes successfully receive all packets from the sink, while the second stage is for noncore nodes to recover lost data from the core nodes. GARUDA further studies destination-related reliability. In contrast, PSFQ consists of three "operations": *pump*, *fetch*, and *report operations*. In pump operation, the sink slowly and periodically broadcasts packets to its neighbors until all data fragments have been sent out. In fetch operation, a sensor node goes into fetch mode once a sequence number gap in a file fragment is detected. It also sends a NACK in reverse path to recover the missing fragment. PSFQ does not propagate NACK messages in order to avoid message implosion. Specifically, the received NACK at an intermediate node will not be relayed unless the number of NACKs that this node has received exceeds a predefined threshold and the lost segments requested by this NACK are unavailable at this node. Finally, in report operation, the sink provides the sensor nodes' feedback information on data delivery status through a simple and scalable hop-by-hop reporting mechanism. PSFQ can be configured to use all the bandwidth and thus overcome the delay caused by the slow pump.

Table 2. Reliable transport protocols for WSNs. LDN: loss detection and notification; LR: loss recovery

Features	Protoc					
	End-to-end		Hop-by-hop			
	STCP [1]	**ESRT [2]**	**RMST [13]**	**RBC [14]**	**GARUDA [3]**	**PSFQ [10]**
Direction	Upstream	Upstream	Upstream	Upstream	Downstream	Downstream
LDN	ACK and NACK	No	NACK	IACK	NACK	NACK
LR	End-to-end	No	Hop-by-hop	Hop-by-hop	Two-tier two-stage loss recovery	Hop-by-hop
Reliability	Event and packet reliability	Event reliability	Packet reliability	Packet reliability	Packet reliability and destination-related reliability	Packet reliability

Protocols for Congestion Control and Reliability

STCP is a generic end-to-end upstream transport protocol. It provides both congestion control and reliability, allocating most responsibility at the sink. Intermediate nodes detect congestion based on queue length and notify the sink by setting a bit in the packet headers. This is network-assisted, end-to-end congestion control. One of the novelties in STCP is that it provides controlled variable reliability utilizing the diversity in applications. For example, STCP uses NACK-based end-to-end retransmission for applications producing continuous flows, and ACK-based end-to-end retransmission for event- driven applications.

3.2 OSI OF WIRELESS SENSOR NETWORK

The standard structural design for WSN follows the OSI layer model which consists of five sub-sections namely the application, transport, network, data link and physical layers. The following figure describes the structure design OSI of WSN;

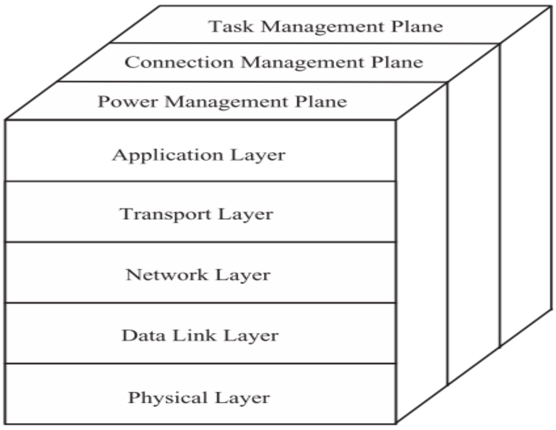

Figure 5: OSI Layers of WSN [32]

The Application layer handles traffics and provides a platform for different kinds of applications to interpret the data into meaningful information or transmit further queries to obtain a specific data needed during a period of time. Sensor applications deployed in various areas in recent years such as environment, missions, medicals and, traffic. An additional layer call transport layer which ensures consistency and congestion avoidance, the protocols in this layer have been developed to be used for upstream -user to sink, for instance, ESRT, STCP and DSTN or downstream -sink to the user, for instance, PSFQ and GARUDA. The techniques apply various protocols to discover loss detection (ACK, NACK) and loss recovery [23]. Normally the transport layer protocol is partitioned into two sub-sections: Packet driven and Event driven. In Packet driven, the packet transmitted from the source should arrive at the target destination. In Event driven, any event which has taken place must be able to be detected and acknowledge as notification to reach the sink [25]. Furthermore, Network layer and the main function of this layer is for routing and the main resource constraints are energy supply, limited memory and buffers. The concept behind routing is to be able to discover reliable, efficient disused paths according to pre- determined techniques called metric, and it's quite unique from protocol to protocol [1, 5]. Some routing protocols for this layer are categorized into flat routing, for instance, direct diffusion, in addition other categorizes is hierarchal routing, for instance, LEACH. Finally, location routing such as GAF protocol. Data delivery models can be divided into time-continuous driven, query driven and event driven divisions. The data link layer is accountable for multiplexing data streams, data frame detection, Medium Access Control (MAC), controlling of error, ensure consistency of packet delivery from the point to point or from point to multipoint. MAC for instance is essential for implementing channel access policies, scheduling, buffer management and controlling of errors and is important for the Sensor network because of its benefits of ensuring energy efficiency, consistency and delay reduction and throughput [24]. The physical layer allows the provision of an interface which is used to broadcast streams of bits across a physical medium. It also selects frequency, carrier frequency generation, signal detection, modulation and data encryption for transmission purposes. IEEE 802.15.4 is the recommended benchmark a lower geographical area for WSN because of its low cost, complexity, energy consumption, range of communication to ensure maximization of power supply [26]. The OSI protocol is further categorized under management plans diagonally to all the layers including power, connection, and task management.

- Power Management Plane: The main goal for the power management plan is to take charge of managing the power supplies for all the different sections of the sensor such as sensing data, processing, broadcasting and responses that depend on a resourceful power management scheme at every phase of protocol layers. For instance, at the MAC layer, to conserve energy a sensor node might switch off the transceiver if there is not data to transmit and receive. At the network layer, a sensor node may select a neighbor node with the most residual energy as its next hop to the sink [24].

- Connection Management Plane: The handling of configuration and re-configuration of the sensor nodes are through the connection management plan which ensure continuous connectivity and node maintenance of the network whenever changes to the topology due to break down of nodes, a mobile movement occurrence and node addition.

- Task Management Plane: Allocation of tasks or schedule the sensing between the sensor nodes is the main duty of the task management plane. This procedure ensures energy efficiency improvement thereby network lifetime is increased. Deployment of sensor nodes is densely populated in the sensing sections so redundancy might occur since not every sensor node around the sensing area will the chance to perform similar sensing schedules. So that's why management techniques are applied to perform sharing of schedules for several sensors nodes .

IV. MOTIVATIONS FOR USING MULTIPATH ROUTING APPROACH

Multipath routing schemes does improve efficiency wireless sensor and ad hoc networks performance. The following are the motivational benefits to be derived when multipath routing techniques are used.

4.1 Reliability and Fault-Tolerance

In view of rapid time change characteristics of dynamic network topology, low-power wireless links and frequently wireless interference transmitting a reliable packet in a wireless network is a difficult task. As the primary inspiration of multipath routing in sensor networks were to give route resilience and the transmission of reliable data. Fault tolerance in sensor network simply means if a node cannot relay the packets in the direction of the sink, available alternative paths are used to prevent packets from failures coming from either the node or link. The scheme is such that so far as alternative paths are available from a target area to the sink node, packet transmitting can be continued without any interruption even in the case of path failure. Moreover multiple paths are also used concurrently to rise up the reliability of packet transmission. There are two ways of providing data transmission reliability simultaneously in multipath routing; the first technique is founded by sending numerous copies of the original data across various routes to allow recovery of data from several route failures. So the reliability of data transmission is assured when at least one route is able to forward data safely [11, 16]. The second technique is erasure coding which certain protocol used to extract reliability performance from several systems. For this approach, every source node inserts extra information to the original data before distributes the packets across different routes. So in case of routes failure to send packets to the sink, data transmission can still continue by reconstructing packets from previous good routes.

4.2 Load Balancing and Bandwidth Aggregation

Resource constrains in sensor nodes illustrates that the rigorous traffic loads in high-data rate applications are subjected to congestion, leading to degradation of network performance. To handle this issue, data dissemination algorithms can profit from the high density of sensor network to raise the capability of network by employing several network resources. Multipath routing technique therefore produced the most convenient solution in supporting the bandwidth conditions of various applications to decrease the possibility of network congestion through separation of network traffic across several routes. Moreover, the dissemination of network traffic across numerous sensor nodes might contribute to equitable energy consumption between the nodes and extend the lifetime of the network. However in radio communication, the transmission character of the broadcast prevents attaining of such goals, the reason being that in single-channel wireless network, sensor nodes work with shared wireless channel to correspond with among nodes. So the simultaneous operations of neighbouring routes contribute to immense inter-path interference that increases the possibility of packet collision at the nodes in the direction of active routes. This problem is known as route coupling effect, which relatively hinders the performance of multipath routing [27].

4.3 QoS Improvement

QoS is measured in the terms of throughput; end-to-end latency and lastly delivery data ration which are all essential goals in developing multipath routing protocols for various kinds of networks. Routes which have been discovered with several properties might be employed to spread network traffic on the conditions of QoS demands of the applications for which the multipath routing is intended for. For example, real-time critical data might be sent through high capacity routes having lesser delays, while the delay non-critical packets might be relay through non-optimal routes with high end-to-end delays. Additionally unlike single- path routing method, multipath routing technique sustains QoS demands of the designed application whenever routes failures happen by channeling network traffic to alternative active routes. But because of lack of link layer problems in single- channel wireless network, enhancing network throughput and delivery data ratio by concurrent multipath routing for sensor networks will be difficult when compared with wired networks [11]. The majority of the proposed routing protocols for WSN are focusing on efficiently using extremely constrained resources, in particular the energy. On the other hand, one significant factor of the routing protocols, the QoS routing has not been paid enough attention from researchers. In order to minimizing energy consumption, it is also significant to deem QoS requirements such as the delay, reliability, throughput in routing in WSNs. The authors in [28] have addresses the problem of QoS routing in order to improve energy consumption in WSNs through formulating a path- based energy minimization problem subject to QoS routing constraints expressed in terms of delay, geo-spatial energy consumption and the reliability. In addition the authors [58] have proposed a novel QoS-aware routing protocol to support high data rate for WMSNs. Being multichannel multipath, the routing decision is made according to the dynamic adjustment of the required bandwidth and path- length-based proportional delay differentiation for real-time data. In [29] author proposed a multipath method which employs the virtual grid, to meet the real-time requirements. In order to choose one of multi-paths depends on the service differentiation, the proposed method uses numerous information such as the size and transfer period of sensed data. Besides to an existing path, the algorithm dynamically chooses an alternative path according to multipath environments. Furthermore, it allocates the shortest path to the sensed data with most strict time. Authors [30], presented a Multiconstrained QoS multipath (MCMP) routing in WSN. Based on this model, an approximation of local multipath routing algorithm is explored to provide soft-QoS under multiple constraints, such as delay and reliability. This MCMP routing algorithm trades precise link information for sustainable computation, memory and overhead for resource limited sensor nodes.

4.4 Energy Efficient

One of the design challenges confronting wireless sensor network is the issue of limited power supply for sensor nodes. Resources for wireless sensor networks are vast; especially hundreds and thousands of sensor nodes which all need adequate supply of energy to perform effectively. So a usage of energy is a pre-requisite for maximization of the entire lifetime of the network. In single path routing, for example if the same optimal paths are used continuously all the time, some nodes might deplete their source of energy at a quicker rate therefore leading to network partition [16]. An Energy Efficient Multi-path Routing Protocol is proposed for WSN‘s [31]. The protocol argues that, when using the minimum energy, path will dissolve the nodes energy rapidly and the time taken to find out an alternate path will increase. The protocol employ multiple paths between the source and the sink which is intended to grant a reliable transmission environment with less energy consumption, by efficiently using the energy availability of the nodes to discover multiple routes to the destination. For the purpose of real-time transmission of multimedia data, authors [32] presented a new QoS protocol which called Real time Energy Aware (REAR) applies to WSNs. In this protocol the metadata is employing to establish multipath routing for decrease the energy consumption. In [33], the authors proposed an energy-efficient multipath routing protocol for WSNs and distribute the traffic through the multiple paths which have discovered based on their cost, which depends on the energy levels and the hop distances of nodes along each path.

4.5 Reduced Delay

When using the single path routing protocol in wireless sensor network, if a route or path in case of node failure, it implies that a fresh discovery of path procedures should be undertaken again to discover routes which are new contributing to delay of route discovery. Delays in multiple routing are diminished because of backup paths identifications during the period of route discovery. The main aim of multipath routing protocols is to enable utmost utilization of the network lifetime is operational and meet the intended observation schedules [34].

V. OVERALL DISCUSSION

Efficient energy, fault tolerance and QoS multipath routing protocols are some of the essentials components in wireless sensor networks because balanced routing decreases energy expenditure at sensor nodes. An efficient energy multi-path routing have the capability to discover multiple routes with high time-efficiency and energy- efficiency. The load balancing algorithm attempts to apportion traffic to every route optimally resulting in node energy efficiency, lower average delay and control overhead. Fault tolerant routing associated with sensor’s fault owing to battery depletion or unreliable wireless links or nodes. To achieve this task, source nodes apply erasure coding, in order to code and transmit packets across multiple disjoint routes to the sink so as to distribute the load and prolong network lifetime. Quality of Service (QoS) multipath routing balances between the energy consumption and specific predefined metrics required by the various sensor applications. The fundamental key of these metrics is to ensure efficient and point to point reliability, average transmission delays, the optimal routes and selections to the sink.

VI. CONCLUSIONS AND FUTURE DIRECTIONS

This research paper highlights the different concepts of routing protocols with specific reference to energy efficient, fault-tolerance, QoS in multipath routing protocols and its implications of data transmissions on wireless sensor network. There was also a description of the various multipath routing protocols being used in sensor applications for data transmission. The benefits of applying such multipath routing protocols resulted in numerous kinds of multipath methods such as path disjointed, path chooser, traffic distribution, and path maintenance, performance indicators, route maintenance, and number of paths for efficient energy, fault-tolerance, QoS in multipath routing protocols. A brief summary of the protocols are illustrated presenting their distinct structures, processes and characteristics. However a lot of research work have been undertaken for multipath routing protocols as discovered from the research, a lot more needed to be done as mobile devices and technology keeps evolving. In the future, another research will be attempted which key aim will be to investigate the possibility of discovering the various energy-aware protocols to maximize efficient energy conservations and to ensure efficient and reliable data transmission.

Multipath routing protocols improve the load balancing and quality of service in WSN and also provide reliable communication. This paper investigates various multi-path routing protocols of the WSN in the literature and illustrates its benefits. The main elements of these schemes and their classifications based on their attributes have been also discussed. Additionally presented an overview of transport protocols and their design issues in WSNs. The ideal transport protocol for WSNs should have the following characteristics: high energy efficiency, flexible reliability, and guaranteed application- dependent QoS. Although some transport protocols have been proposed, there are several opportunities for performance optimization like:

First, we are interested in designing WSN transport protocols that support node priority. The existing transport protocols, with the exception of STCP, consider only a single type of sensing device. It is not uncommon that a node be equipped with multiple types of sensors (e.g., temperature and humidity measurements). Thus, nodes may have different priorities and can generate sensory data with different features and requirements in terms of loss, bandwidth, and delay requirements. Different mechanisms are needed to deal with this diversity.

Second, the existing transport protocols only consider single path routing. When multipath routing is used in the network layer, issues such as fairness arise and need to be addressed.

Third, all the existing schemes either address congestion control or loss recovery; none of them (except STCP) investigate both problems systematically. In fact, a proper congestion control should reduce packet loss and provide better through- put. Furthermore, loss recovery can enhance reliability. Therefore, transport protocols should consider both issues, together with considerations of performance optimization, energy efficiency, and other performance metrics.

Finally, the existing transport protocols rarely consider cross-layer interactions. In a WSN, link-level performance such as bit-error rate can significantly impact the performance of the transport layer protocol; similarly, routing can affect hop-by-hop retransmissions. Therefore, cross-layer optimization is highly desirable.

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