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Research Paper

Routing Protocols for Wireless Sensor Networks: Classifications and Challenges

*Manal Abdullah[1], Aisha Ehsan[2]
Department of Information System, Faculty of Computing and Information Technology FCIT,
King Abdulaziz University KAU, Jeddah, Saudi Arabia

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ABSTRACT:- *Sensor is an object used to gather information about a physical process, including the occurrence of events. Hence Wireless Sensor Network (WSN) consists of individual sensors or nodes that collaborate to fulfill certain task; and these nodes use wireless communication to enable their collaboration. Routing protocols are in charge of discovering and maintaining the routes in the network. However, the appropriateness of a particular routing protocol mainly depends on the capabilities of the nodes and on the application requirements. In this paper, we classify the routing protocols proposed for WSN. The classification is based on five main key factors namely: energy efficiency, operational model, routing objectives, network architecture, and route selection. Some of these criteria are further detailed classified. We also highlighted some overlapping characteristics of some protocols. The design challenges of WSN are discussed with its application area.*

Keywords:- *Routing classification , Routing protocol , Sensor, sensor network topology, WSN.*

I. INTRODUCTION

Wireless Sensor networks are dense wireless networks of small, inexpensive, low-power, distributed autonomous sensors which accumulate and propagate environmental data to facilitate monitoring and controlling of physical environments from remote locations with better accuracy. Generally it is assumed that each sensor in a network has certain constraints with respect to its energy source, power, memory and computational capabilities.

In WSN, each spatially distributed sensor node communicates with each other to forward their sensed information to a central processing unit/sink or carry out some local coordination such as data fusion. The sink nodes have accesses to infrastructure networks like the Internet from where the end user fetches the sensed data [1]. The most modern networks are bi-directional, also enabling control of sensor activity. [2]

In Fig. 1, two kinds of network topologies are shown. The sensor nodes either form a flat network topology where sensor nodes also act as routers and transfer data to a sink through multi-hop routing, or a hierarchical network topology where more powerful fixed or mobile relays are used to collect and route the sensor data to a sink. The mechanism of the sensor may be seismic (by proximity to target), magnetic, thermal, visual (a line of sight to the target), infrared, acoustic (by propagation like a wave with possible bending), or radar. A smart sensor is also capable of self-identification and self-diagnosis. Basic topology architecture for WSN is depicted in Fig 1.

The ideal wireless sensor network is alleged to be scalable, fault tolerance, little power consumption, smart and software programmable, efficient, competent of fast data acquisition, reliable and accurate over long term, low cost and required no real maintenance.[3]

The rest of the paper is organized as follows: Section 2 is the hardware platform of the sensors. Section 3 describes the sensor network characteristics and its performance. Section 4 briefly illustrates the WSN design challenges. Section 5 concerning routing issues and the main challenges in designing routing protocols for WSN. Section 6 is about the related work. Section 7 introduces a classification tree for an inclusive taxonomy of

*Corresponding Author: Manal Abdullah
Department of Information System, Faculty of Computing and Information Technology FCIT,
King Abdulaziz University KAU, Jeddah, Saudi Arabia

the routing protocols in WSN according to different parameters. Then Section 8 encloses brief description for each category along with routing protocols falling in these categories. Finally we conclude in section 9

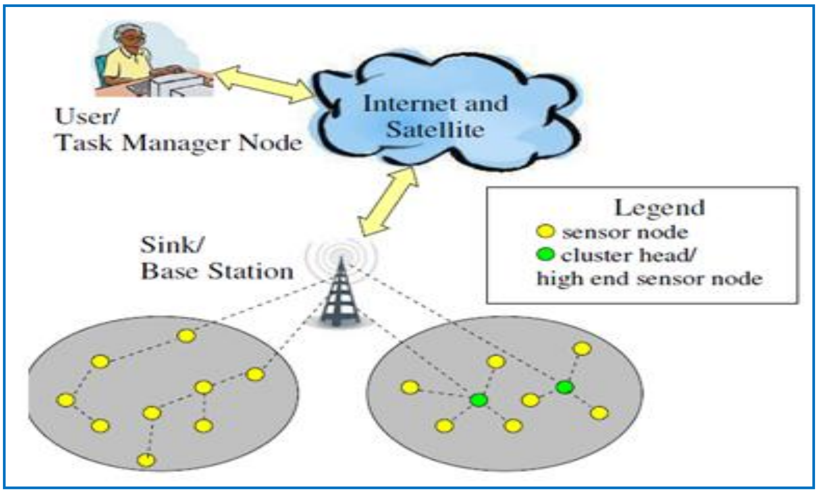


Figure 1: Operation of WSN Flat and Hierarchical sensor network topology [1]

II. HARDWARE PLATFORM

Usually, the wireless sensor networks are composed of enormous number of sensor nodes scattered randomly in the sensor field. Each smart sensor node is a combination of sensing, processing and communication technologies and so each sensor node is composed of several hardware components which includes a radio transceiver (usually with a single Omni-directional antenna) , an embedded processor (one or more microcontrollers, CPU, or DSP chips), internal and external memories(program, data and flash memories), a power source(e.g. batteries and solar cells) and house various sensors(which are the interface to the physical world that could be either Passive Omni directional sensors, passive narrow-beam sensors or active sensors) and actuators.[3]

Fig 2 is the communication architecture of WSN as well the schematic diagram of sensor node components in which sensor nodes are represented as small circles. Basically, each sensor node comprises ***sensing unit*** which senses the change of parameters then sensed electrical signals are converted to the digital domain, which is used as input to the ***processing unit***, the ***memory*** helps processing of the tasks, ***transmission unit*** consists of transceiver used for communicating with other sensors or the base stations or sinks in WSN, ***mobilizer***, ***position finding system***, and ***power units*** (some of these components are optional like the mobilizer).[4][5]

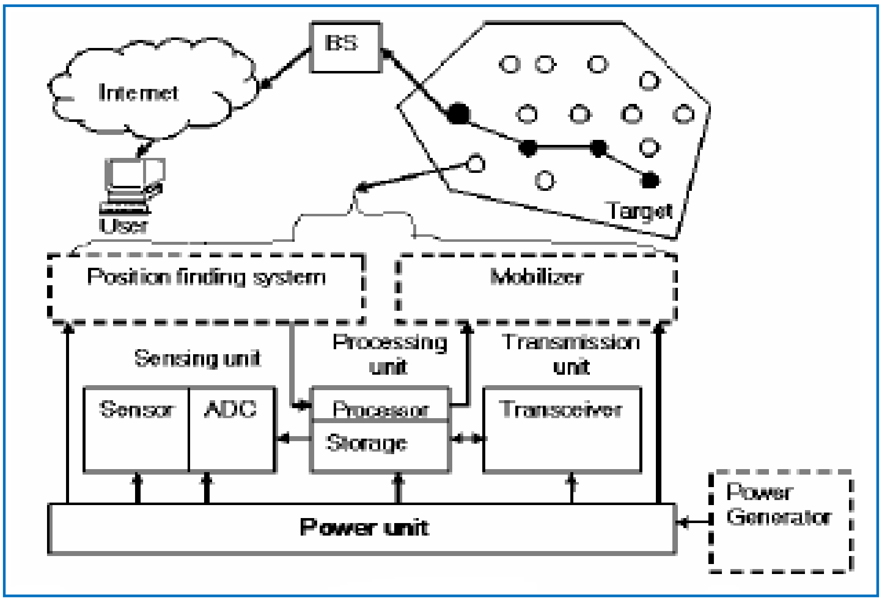


Figure 2: Structural view of Sensor Network [5]

III. SENSOR NETWORKS CHARACTERISTICS AND PERFORMANCE

As compared to other categories of wireless networks, wireless sensor networks possess two fundamental characteristics: multi-hop transmission and constrained energy sources. In general, data packets from the source node need to traverse multiple hops before they reach the destination. Second, since sensors are usually small and inexpensive, they are assumed to have constrained energy sources, and any protocols to be deployed in sensor networks need to be aware of energy usage. These two characteristics have important implications to the fundamental performance limits of wireless sensor networks.

IV. WSNS NETWORK DESIGN CHALLENGES

Depending on the application, different architectures and design goals/constraints have been considered for sensor networks. Since the performance of a routing protocol is closely related to the architectural model, so the design of the routing protocols for WSN is challenging. This section attempts to list down the main aspects involved in the design challenges of sensor networks. [6][7]

1.1 Limited Energy Capacity

Energy poses a big challenge for the network designers in hostile environments. Since sensor nodes are battery powered, they have limited energy capacity. So when the energy of a sensor reaches a certain threshold, they become faulty and are not able to function properly which affects the overall network performance to great extend. Consequently the routing protocols designed for sensors should be as energy efficient as possible to extend their lifetime, and hence prolong the network lifetime.

1.2 Sensor Location

Managing the locations of the sensors is another challenge that features the design of the routing protocols. Most of the proposed protocols assume that the sensors either are equipped with GPS receivers or use some localization technique to learn about their locations.

1.3 Limited Hardware Resources

Sensors can perform only limited computational functionalities due to their limited processing and storage capacities beside limited energy capacity. These hardware constraints present many challenges in software development and network protocol design for sensor networks.

1.4 Node Deployment

Topological deployment of the sensors in WSNs is application dependent and finally affects the performance of the routing protocol. The deployment is either deterministic or self-organizing. In deterministic situations, the sensors are manually placed and data is routed through pre-determined paths. However in self-organizing systems, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner. In that infrastructure, the position of the sink or the cluster-head is also crucial in terms of energy efficiency and performance.

1.5 Network Characteristics and Unreliable Environment

The WSN is consistently prone to frequent topology changes because of extremely vulnerable to node failure, sensors addition, deletion, node damage, link failure, sensor energy exhaustion etc. also susceptible to noise, time consistency and errors due to wireless nature of the network. So the network routing protocol/mechanism be capable of sustain the network topology dynamics, increase network size, energy consumption level, sensor nodes mobility and their related issues like coverage and connectivity to retain specific application requirements.

1.6 Data Aggregation

In WSN the redundancy of data generated from sensor nodes is a key concern. Similar packets from multiple nodes can be aggregated to reduce the extra overhead due to number of the transmissions. Many proposed routing protocols are using data aggregation technique to achieve energy efficiency and data transfer optimization.

1.7 Diverse sensing application requirements

Sensors networks have a wide range of diverse applications. Each application has its own specifications and constraints different from other application. There is no network protocol which can fully meet the criteria of all applications. Therefore the routing protocols designed should compute an optimal path and guarantee the accurate data delivery to the sink on time.

1.8 Scalability

Scalability is very important in WSN as the network size can grow rapidly. So the routing protocols should be designed to work consistently, keeping in consideration that sensors may not necessarily have the same capabilities in terms of energy, processing, sensing, and particularly communication. Furthermore, care should be taken to design routing protocol as there could be asymmetric communication between sensors instead of symmetric (a pair of sensors may not be able to have communication in both directions).

V. ROUTING ISSUES

The topology of the WSNs can be simply star network to an advanced multihop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

Routing techniques are required for sending data between sensor nodes and the base stations for communication. The ways how to effectively route the collected data among nodes is very important as well very challenging in WSNs because of many constraints of sensor nodes and several discriminated characteristics of WSN that distinguish them from contemporary communication and wireless ad hoc networks.

Routing in WSN is very different from conventional routing in fixed network in various ways: In WSNs there is no infrastructure, it is unfeasible to build global addressing and routing algorithms exactly as for conventional IP-based protocols for the deployment of steep number of energy and processing capacity constrained sensor nodes, the flow of sensed data from multiple sources to a particular sink in all sensor applications, significant redundancy in The generated data traffic within the locality of a phenomenon needs to be exploited by the data and goal-oriented routing protocols to improve energy and bandwidth utilization, also sensor nodes are tightly constrained in terms of limited transmission range, limited energy resources, processing and storage capacity, transmission power and thus require careful resource management. So Routing in wireless sensor networks have to ensure reliable multi hop communication under these conditions.[6][8][9]

Due to these differences and constraints, many algorithms/routing protocols have been proposed for routing data in wireless sensor networks to ensure reliable multi hop communication. These routing mechanisms have considered the characteristics of sensor nodes along with the application and architecture requirements.

5.1 Main Challenges in Designing Routing Protocols For WSN

The data transmission from the target area towards the sink node is a main task. Moreover the process to forward the data packets between each pair of source-sink nodes is an important issue in WSNs. So the challenge of routing in these networks because of intrinsic features of low power wireless sensor networks are: ability of routing protocols to support data transmission over long distances regardless of network size, issue of fault tolerance or reliability i.e. normal network operation should not interrupt due to some of the active nodes failure during network operation for the reason of energy depletion, hardware breakdown or environmental factors of the sensor nodes, production cost[16], transmission media[16]. Routing and data dissemination should be performed with efficient network resource utilization since sensor nodes are tightly limited in terms of power supply, processing and memory capacity and available bandwidth, furthermore routing protocol should satisfy the QoS demands of the application for which the network is deployed, data aggression / fusion should be done by using different functions such as suppression, min, max and average to achieve energy efficient and traffic optimization in routing protocols so that network lifetime is enhanced.

VI. RELATED WORK

There are many challenges that affect the performance of routing protocols resulting in overall WSN performance degradation. These challenges includes resource constrained nature of WSN which impel many challenges in its design and operation and also various number of applications having different constraints in their nature add more challenges for these networks to achieve application expectations.

There are various surveys proposing routing protocols for WSN, several describing and analyzing the general routing strategies proposed for sensor networks and many papers classifying the routing protocols for WSN into different categories considering different parameters . However none of these papers has provided taxonomy on complete categories of routing protocols for wireless sensor networks.

[2] Presents the classification based on mode of functioning, based on node participation style and network structure based routing protocols. [3] Routing protocol in WSNs are classified into 3 classes depending on network structure .also some of the multipath routing protocols are discussed. Furthermore comparing and summarizing the performances of routing protocols is done. [10] Presents the comprehensive taxonomy on the existing multipath routing protocols for WSN along with explaining the operation of different protocols in detail. Also they compare and summarize the state-of- the art multipath routing techniques from the network application point of view. In [11], main focus is towards the modification and enhancements performed to DD routing protocol with the brief description of the different approaches used in routing protocol along with the traditional taxonomy of routing protocols. In [6], they have divided major routing protocols for WSN into seven categories. Also they briefly reviewed few routing protocols in each category. [5] Conducted simulation for three different types routing protocols to analyze their performances including the power consumption and

overall network performance. In [12], the routing protocols are divided into two broad categories, network architecture based routing protocols and operation based routing protocols.

To the best of our knowledge, this paper is the first endeavor to come up with an extensive taxonomy of the routing protocols for WSNs taking into account most parameters required for their classification.

VII. ROUTING PROTOCOLS CLASSIFICATION FOR WSN

Different routing protocols are proposed for WSN taking into account the challenges that affect the performance of routing protocols resulting in overall WSN performance degradation. These protocols can be classified according to different parameters as depicted with the classification tree in Fig 3.

- Routing Objectives i.e. non real time, network lifetime and real time.
- Architecture Based routing: Data Centric, Hierarchical, Location-Based.
- Routing based on Power Transmission i.e. Fixed or Adjustable.
- Operational Base Routing which includes path selection, QoS based, delivery model.
- Routing based on the Route Selection: Proactive, reactive and hybrid.

The following subsections are detailed description of this classification.

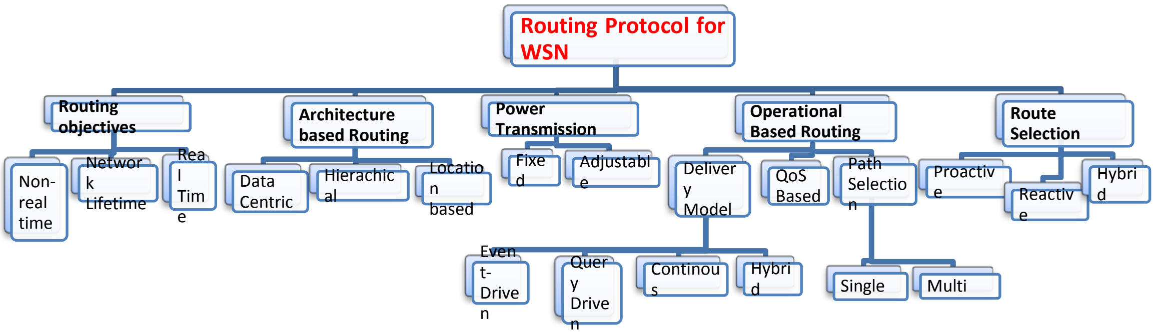


Figure 3: Classification of Routing Protocols in WSN

7.1 Routing Objectives

Some sensor applications only require the successful delivery of messages between a source and a destination. However, there are applications that need even more assurance. These are the real-time requirements of the message delivery, and in parallel, the maximization of network lifetime [13].

7.1.1 Non-Real Time Delivery

The assurance of message delivery is indispensable for all routing protocols. It means that the protocol should always find the route between the communicating nodes, if it really exists. This correctness property can be proven in a formal way, while the average-case performance can be evaluated by measuring the message delivery ratio [14].

Examples: Directed diffusion, SMECN, MECN, ACQUIRE, GEAR, Rumor Routing [13][15].

7.1.2 Real-Time Delivery

Some applications require that a message must be delivered within a specified time, otherwise the message becomes useless or its information content is decreasing after the time bound. Therefore, the main objective of these protocols is to completely control the network delay. The average-case performance of these protocols can be evaluated by measuring the message delivery ratio with time constraints [14].

Examples: SPEED, SAR [13].

7.1.3 Network Lifetime

This protocol objective is crucial for those networks, where the application must run on sensor nodes as long as possible. The protocols aiming this concern try to balance the energy consumption equally among nodes considering their residual energy levels. However, the metric used to determine the network lifetime is also application dependent. Most protocols assume that every node is equally important and they use the time until the first node dies as a metric, or the average energy consumption of the nodes as another metric. If nodes are not equally important, then the time until the last or high-priority nodes die can be a reasonable metric [14].

Examples: GBR, GAF, CADR, TTDD, PEGASIS, SPIN, LEACH, HPAR, TEEN, APTEEN, MCFA [15], [13].

7.2 Architecture Based Routing

Protocols are divided according to the structure of network which is very crucial for the required operation. The protocols included in this category are further divided into three subcategories according to their functionalities.

7.2.1 Data-Centric (DC)

In data-centric routing, the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute-based naming is necessary to specify the properties of data [7]. The main idea of the DC is to combine the data coming from different sources en-route (in-network aggregation) by eliminating redundancy, minimizing the number of transmissions; thus saving network energy and prolonging its lifetime. Unlike traditional end-to-end routing, DC routing finds routes from multiple sources to a single destination that allows in-network consolidation of redundant data.

SPIN, Directed diffusion, Rumor Routing, GBR, CADR, ACQUIRE, MCFA[7], EAR[10] and COUGAR,EAD, STCP[27][8] protocols are DC because they determine the next-hop on the route purely based on the query content which sent to certain region [7].

7.2.2 Hierarchical

The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensor's proximity to the cluster head [7]. Although this approach can provide higher network scalability, clustering operation and cluster head replacement (which is required to prevent fast energy depletion of the cluster heads) impose high signaling overhead to the network. [10]

LEACH, TEEN, APTEEN, PEGASIS, Hierarchical-PEGASIS[27] HPAR, , and TTDD are hierarchical protocols because all nodes in network forward a message for a node that is in a higher hierarchy level than the sender [7][15].

7.2.3 Location-Based

In this kind of network architecture, sensor nodes are scattered randomly in an area of interest and mostly known by the geographic position where they are deployed. They are located mostly by means of GPS. The distance between nodes is estimated by the signal strength received from those nodes and coordinates are calculated by exchanging information between neighboring nodes [12]. However, since localization support requires specific hardware components and imposes significant computational overhead to the sensor nodes, this approach cannot be easily used in resource-constrained wireless sensor networks.

MECN, SMECN [3], GAF, GEAR, Geographic Routing in Lossy WSNs [27] SAR, and SPEED are examples of Location-Based. In these protocols the location information is needed in order to calculate the distance between two particular nodes so there is no addressing scheme in this category [7][12][15].

7.3 Transmission Power

The method to mitigate energy consumption is to adjust transmission power which can be defined by the amount of energy drawn for communication. Several improvements in the operation of WSNs can be done by controlling the transmission power such as the establishment of links with higher reliability, communication with the minimum energy cost, and better reuse of the medium [16]. The main approaches of transmission power needed by node to transmit a data packet are fixed or variable amount.

7.3.1 Fixed Transmission Power

In this transmission each sensor node transmits each message using the same energy level. When communicating at a fixed transmission power, nodes waste energy since some links already have a high probability of a successful delivery [16].

SPIN, Directed diffusion, Rumor Routing, LEACH, GAF, GEAR, GBR, CADR, MCFA, PEGASIS, TTDD, ACQUIRE, TEEN, APTEEN, and SPEED these protocols used the same energy level in their transmission of data [13], [15].

7.3.2 Dynamically Adjustable Transmission Power

In this transmission every node can calculate what energy level should be used to transmit a message to a neighboring node. Compared to the fixed transmission-power control, the dynamic transmission-power control improves the power consumption up to 16% for convergence traffic, but no noticeable performance improvements for aggregation traffic [17]. The effect of dynamic transmission-power control becomes larger as we reduce the radio duty cycle, with 37% power savings at a 10% duty cycle [17]. This result suggests that dynamic transmission-power control is most useful in combination of low-power MAC protocols which implement radio low duty cycling.

MECN, SMECN, SAR, and HPAR protocols use different energy level in their transmission of data [13], [15].

7.4 Operational Based Routing

WSNs applications are categorized according to their functionalities. Hence routing protocols are classified according to their operations to meet these functionalities. The rationale behind their classification is to achieve optimal performance and to save the scarce resources of the network [12].

7.4.1 Data Delivery Model

Data delivery models determine when the data collected by the node has to be delivered. Depending on the application of the sensor network, there are four data delivery models to the sink [18].

7.4.1.1 Continuous Model

In this model each sensor node generally collects data of the same size and periodically transfers this data to base station by multi-hop communication.

Examples: MCFA, SPEED, LEACH, GAF, TEEN, PEGASIS, CADR, SAR, MECN, SMECN [13], [18].

7.4.1.2 Query-Driven Model

In this model the transmission of data is triggered when query is generated by the sink regarding the desired sensing task. If a node senses any related information, it sends back its collected data towards the sink node through the reverse path.

Examples: Rumor Routing, Directed Diffusion [10], ACQUIRE, GEAR (demand driven), SPIN [18].

7.4.1.3 Event-Driven Model

In this model the transmission of data is triggered only is the event of interest occurs. In this case, the observer is interested only in the occurrence of a specific phenomenon or set of phenomena.

Examples: TTDD[13][15][18].

7.4.1.4 Hybrid Model

This model is using a combination of continuous, event-driven and query-driven data delivery.

Examples: APTEEN, GBR [18].

7.4.2 Qos Based

QoS based protocols are designed to satisfy QoS demands of different applications (e.g., delay, reliability, and bandwidth). The main aim of these approaches is to establish a trade-off between energy consumption and data quality. [10]

Sequence Assignment Routing (SAR) protocol[19], Minimum Energy Metric (MEM) [19], SPEED, Multipath Multi-SPEED (MMSPEED), Energy-aware QoS Routing Protocol and Delay-minimum Energy-aware Routing Protocol (DERP) [10], Multi onstrained QoS Multi-Path routing Protocol (MCMP), Message-Initiated Constrained-Based Routing (MCBR),Energy Constrained Multi-Path routing Protocol (ECMP),EQSR, QuEst can be considered as the QoS-aware routing protocols[20].

In SAR, a sensor node selects a tree for data to be routed back to the sink according to energy resources and an additive QoS measure. MEM algorithm minimizes power consumed by each packet without considering its priority. SAR consumes less energy compared with MEM and ensures fault tolerance but has the overhead of maintaining table and node state. [19]

7.4.3 Path Selection

In most routing protocols, a node selects only a single path towards the base station, and the only instance of a message (single/single) is forwarded along this single path. However, a node may also select multiple paths, and the node forwards either the single instance of a message on a deterministically or randomly chosen single path (multiple/single) or one copy of a message per path (multiple/multiple) [14].

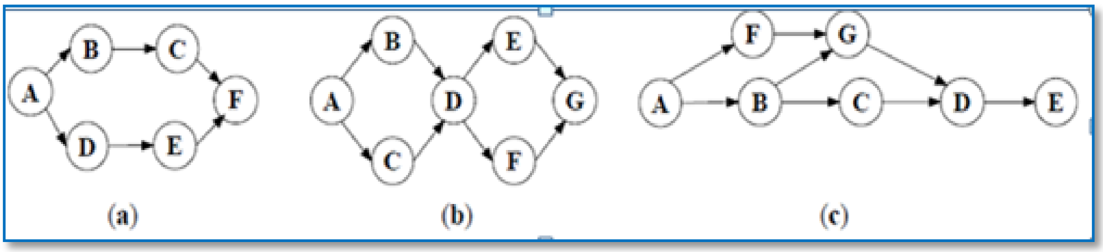
7.4.3.1 Single-Path

In single-path routing, each source sensor sends its data to the sink via the shortest path. One of the main design issues of WSN is to prolong the network lifetime and prevent connectivity degradation by employing energy management techniques. But a single route does not make any solution of in terms of energy because it rapidly drains energy of relay nodes; as a result these nodes die quickly than others [21].
Examples: Rumor Routing, MCFA, SAR, LEACH, PEGASIS, GAF, GBR, ACQUIRE, GEAR, SPEED, MECN, SMECN, HPAR, CADR, TEEN, APTEEN [13], [15], [22], ECRA, Energy Aware Routing Protocol [3]

7.4.3.2 Multi-Path

The term multipath routing has been used to describe the class of routing mechanisms that allow the establishment of multiple paths between source and destination. In this routing, each source sensor finds the first k shortest paths to the sink and divides its load evenly among these paths [6].

Different parameters are used in the existing multipath routing protocols to make routing decisions. Among these parameters, the amount of path disjointedness is the main criterion which is utilized by all the existing multipath routing protocols to discover several paths from each sensor node towards the sink node. Discovered paths can be generally categorized as node-disjoint, link-disjoint, or partially disjoint paths as shown in the Fig. 4.[10]



a) Node-Disjoint Paths   b) Link-Disjoint Paths   c)Partially –Disjoint Paths
Figure 4: Various types of paths disjointness [10]

Multipath approach is used in diverse routing protocols to offer fault tolerance when having unicast routing. The idea is to have an energy efficient path for data forwarding, but to give fault tolerance to possible problems on the path (e.g a sensor node fails), it would be required to have alternative paths that can start in operation when this happens. These paths can be classified into two main types: [11]

- **Disjoint Multi-paths**

The first multipath mechanism we consider constructs a small number of alternate paths that are node-disjoint with the primary path, and with each other, means that in two or more paths from source to sink there is no common node between them. These alternate paths are thus unaffected by failures on the primary path, but can potentially be less desirable (e.g., have longer latency) than the primary path [23].the disadvantage in using this technique is that it tends to generate inefficient alternative paths with large detours [11]. See Fig. 5a

Examples: Directed Diffusion, SPIN, TTDD [23].

- **Braided Multi-paths**

A constructive definition for braided multipath is: for each node on the primary path, find the best path from source to sink that does not contain that node. This alternate best path need not necessarily be completely node-disjoint with the primary path. We call the resulting set of paths (including the primary path) the idealized braided multipath [23].

Braided paths are paths that share one or more nodes along the trajectory from source to sink (also known as meshed multi-path). This solves the problems of disjoint paths and maintains the redundancy of the network. They have the option that enables the use of most of the nodes involved in the primary path and include other(s) that can replace the node(s), which are not available to handle the messages of the application. Energy efficiency is guaranteed if the braided paths are kept as close as possible to the primary one [11]. See Fig 5b

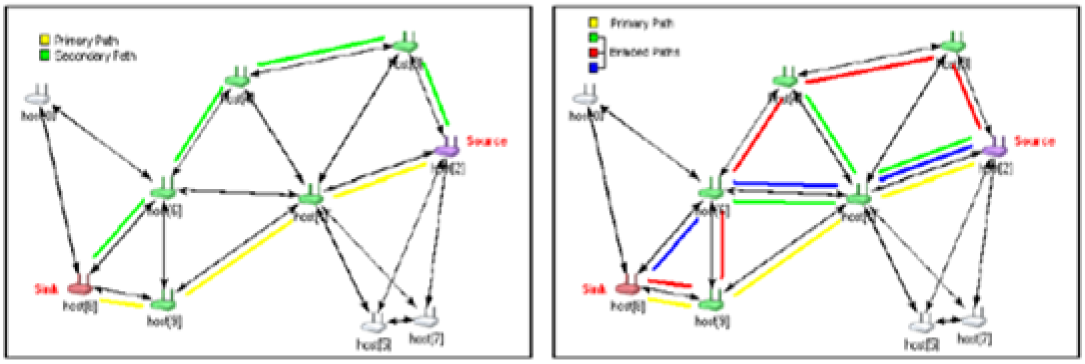


Figure 5: a) Disjoint paths b) Braided paths [11]

The existing multipath routing protocols can be classified into three main categories based on the employed path selection and traffic distribution mechanisms. [10]

1. Alternative Path Routing
2. Multipath Routing for Reliable Data Transmission
3. Multipath Routing for Efficient Resource Utilization

The objective of Alternative Path Routing is to provide fault-tolerant routing and reducing the frequency of route rediscovery process while they provide high path resilience against route failure. e.g DD, Braided multipath routing, Reliable and Energy-Aware Routing.

Multipath Routing protocols for Reliable Data Transmission and Multipath Routing Protocols for Efficient Resource Utilization are concurrent multipath routing.

The objective of Multipath Routing protocols for Reliable Data Transmission is to improve data transmission reliability. E.g. N-to-1 Multipath Routing, MMSPEED, DCHT, EQSR etc. These protocols utilize the packet replication technique or erasure coding in conjunction with the concurrent multipath routing technique to satisfy the reliability requirements of various applications.

The objective of *Multipath* Routing Protocols for Efficient Resource Utilization is congestion control, Bandwidth aggregation and QoS support in terms of delay, throughput, data delivery ratio, and network lifetime.

7.5 Route Selection

The WSN routing protocols can be further classified on the basis of path computation on the acquired information. This classification of protocol is based on how the source node finds a route to a destination node [12].

7.5.1 Proactive Routing Protocols

Are also known as table driven protocols which maintains consistent and accurate routing tables of all network nodes using periodic dissemination of routing information. In this category of routing all routes are computed before their needs [12].

SPIN, Directed Diffusion, LEACH, SPEED, SAR, TTDD, and GBR protocols classified into this category due to keep track of routes to all destinations in routing tables [15][24].

7.5.2 Reactive Routing Protocols

Reactive routing strategies do not maintains the global information of all the nodes in a network rather the route establishment between source and destination is based on its dynamic search according to demand. In order to discover route from source to destination a route discovery query and the reverse path is used for the query replies. Hence, in reactive routing strategies, route selection is on demand using route querying before route establishment. These strategies are different by two ways: by re-establishing and re-computing the path in case of failure occurrence and by reducing communication overhead caused by flooding on networks [12].

Examples of this category are TEEN, GEAR, ACQUIRE, MCFA, PEGASIS, CADR, MECN, and SMECN protocols which acquire routes on demand and avoid saving information about the network topology [24],[15],[7],[25],[26].

7.5.3 Hybrid routing protocols

This strategy is applied to large networks. Hybrid routing strategies contain both proactive and reactive routing strategies. It uses clustering technique which makes the network stable and scalable. The network cloud is divided into many clusters and these clusters are maintained dynamically if a node is added or leave a particular cluster. This strategy uses proactive technique when routing is needed within clusters and reactive technique when routing is needed across the clusters. Hybrid routing exhibit network overhead required maintaining clusters [12].

Rumor Routing, HPAR, GAF, and APTEEN protocols are an example of hybrid routing because their selection route based on a combination of proactive and reactive approaches [24], [15], [25].

VIII. WSN DESIGN CHALLENGES

The variety of WSN applications is hardly fulfilled with unified network design. The data transmission from the target area towards the sink node is a main task. Moreover the process to forward the data packets between each pair of source-sink nodes is an important issue in WSNs. So Routing protocols are one of the major design challenges of WSN due to intrinsic features of low power wireless sensor networks.

Routing protocol for certain application is expected to fulfill the following characteristics: Ability of routing protocols to support data transmission over long distances regardless of network size, issue of fault tolerance or reliability i.e. normal network operation should not interrupt due to some of the active nodes failure during network operation for the reason of energy depletion, hardware breakdown or environmental factors of the sensor nodes, production cost [6][16] since the cost of single node is enough to justify the overall cost of the sensor network. So the cost of each sensor node should be kept low. Routing and data dissemination should be performed with efficient network resource utilization since sensor nodes are tightly limited in terms of power supply, processing and memory capacity and available bandwidth, furthermore routing protocol should satisfy the QoS demands [6] of the application for which the network is deployed .

Routing protocol QoS is defined by a set of attributes like delay, jitter, bandwidth, and packet loss. It is directly related with the type of the network services and routing protocol characteristics. Data aggression / fusion [6] should be done by using different functions such as suppression, min, max and average to achieve energy efficient and traffic optimization in routing protocols so that network lifetime is enhanced. Power consumption [6] is to alleviate due to the obligation such as long life time of sensor networks and restricted storage capacity of sensor.

In multi-hop sensor networks, the multi-functioning of some nodes can cause topology change due to power failure which require new path for data transfer and restructure the network. Operating environment; sensor network can be setup inside large machinery, at the base of the ocean, in a biologically or chemically contaminated field etc. Maintainability [6] as the changes in the environment and in WSN requires a solution that can adapt itself and sustain the services. The flexible programmability [6] is the capability of the routing protocol to modify the processing option of the acquired data and to execute changes and adjustments in their tasks. Scalability; a system is scalable if its effectiveness increases when the hardware is put-on and proportional to the capacity added. Routing schemes make efforts with the vast collection of motes in WSNs which should be scalable enough to talk back to the events take place in the environment.

X. CONCLUSIONS

In this paper we presented a thoroughly classification for routing protocols in WSNs. Many routing protocols, specially designed for sensor networks, are highly dependent on the network application. So, we have highlighted the characteristics of WSN's routing protocols from main five classification perspectives that we consider as most related to the network design. Among the design factors and challenges for WSN's protocols are the energy-awareness and scalability because of the numerous number of sensor nodes involved in the network design.

REFERENCES

[1] QinghuaWang, Ilangko Balasingham "Wireless Sensor Networks - An Introduction" , Dept. of Electronics and Telecommunications, Norwegian University of Science and Technology, Norway.

[2] Darpan, (April 2012) "Power Aware Routing Protocol in WSN". http://www.slideshare.net/darpan_dekivadiya/routing-protocols-for-wireless-sensor-networks, last visited October2013.

[3] Neha Rathi1, Jyoti Saraswat2 and Partha Pratim Bhattacharya3, (September 2012) "A Review on Routing Protocols for Application in Wireless Sensor Networks", International Journal of Distributed and Parallel Systems (IJDPS) Vol.3, No.5, ijdps.2012.3505 39.

[4] Qutaiba I. Ali, INTECH 2012 ALI "Simulation Framework of Wireless Sensor Network (WSN) Using MATLAB/SIMULINK Software", licensee INTECH.

[5] Laiali Almazaydeh, Eman Abdelfattah, Manal Al- Bzoor, and Amer Al- Rahayfeh, "Performance Evaluation of Routing Protocols in Wireless Sensor Networks", International Journal of Computer Science and Information Technology, Volume 2, Number 2, April 2010.

[6] Shio Kumar Singh 1, M P Singh 2, and D K Singh 3 (November 2010), "Routing Protocols in Wireless Sensor Networks" –A Survey, International Journal of Computer Science & Engineering Survey (IJCSES) Vol.1, No.2, ijcses.2010.1206 63.

[7] Kemal Akkaya and Mohamed Younis, "A Survey on Routing Protocols for Wireless Sensor Networks", Department of Computer Science and Electrical Engineering, University of Maryland, Baltimore County.

[8] Hannes Frey, Stefan R¨uhrup, and Ivan Stojmenovi´c, "Routing in Wireless Sensor Networks, Chapter 4.

[9] José Cecílio, Eudisley Anjos, João Costa, Pedro Furtado,University of Coimbra, "Survey on Data Routing in WSN" , DEI/CISUC.

[10] Marjan Radi 1, Behnam Dezfouli 1, Kamalrulnizam Abu Bakar 1 and Malrey Lee 2(Sensors 2012), "Multipath Routing in Wireless Sensor Networks: Survey and Research Challenges", 650-685, ISSN 1424-8220.

[11] Luna-Vazquez, Israel (March 2006), "Implementation and Simulation of Routing Protocols for Wireless Sensor Networks", Master thesis.

[12] Muhammad Ullah, Waqar Ahmad (14 Ma y 2009), "Evaluation of Routing Protocols in Wireless Sensor Networks" , Department of School of Computing Blekinge Institute of Technology RONNEBY SWEDEN, Master Thesis Computer Science.

[13] CecAlio, "Survey on Data Routing in WSN".

[14] Acs, G. and L. Buttyán (December, 2006), "A Taxonomy of Routing Protocols for Wireless Sensor Networks.

[15] Al-Karaki, J.N. and A.E. Kamal (2004), "Routing Techniques in Wireless Sensor Networks: A Survey", Wireless Communications, IEEE, 11(6): p. 6-28.

[16] Correia, L.H.A., et al.(2005), "Transmission Power Control in MAC protocols for Wireless Sensor Networks, ACM.

[17] Jeong, J., D. Culler, and J.H. Oh. (2007), "Empirical Analysis of Transmission Power Control Algorithms for Wireless Sensor Networks", IEEE.

[18] Biradar, R.V., et al. (2009), "Classification and Comparison of Routing Protocols in Wireless Sensor Networks", Special Issue on Computing Security Systems, UbiCC Journal, v 4: p. 704-711.

[19] Sidra Aslam, Farrah Farooq and ShahzadSarwar, (2009) "Power Consumption in Wireless Sensor", FIT'09, December 16–18, 2009, CIIT, Abbottabad, Pakistan.

[20] R.Sumathi* and M.G.Srinivas (2012), "A Survey of QoS Based Routing Protocols for Wireless Sensor Networks", India, J Inf Process Syst, Vol.8, No.4, December 2012.

[21] Rahman, M.M., M.I. Abdullah, and M.S. Hossain, "Level Based Path Selection Technique in Large WSN for Hierarchical Architecture".

[22] Lakafosis, V. and M.M. Tentzeris (2008), "Implementation of multi-hop routing protocols for the dramatic range enhancement of wireless sensor networks", IEEE.

[23] Ganesan, D., et al. (2001), "Highly-Resilient, Energy-Efficient Multipath Routing in Wireless Sensor Network", ACM SIGMOBILE Mobile Computing and Communications Review, 5(4): p. 11-25.

[24] Bhattacharyya, D., T. Kim, and S. Pal, "A Comparative Study of Wireless Sensor Networks and Their Routing Protocols", Sensors, 10(12): p. 10506-10523.

[25] García Villalba, L.J., et al. (2009), "Routing protocols in wireless sensor networks", Sensors, 9(11): p. 8399-8421.

[26] Al-Obaisat, Y. and R. Braun (2006), "On Wireless Sensor Networks: Architectures, Protocols, Applications, and Management", Citeseer.

[27] Almir Davis, Hwa Chang (December 2012), "A Survey of Wireless Sensor Network Architectures", Department of Electrical and Computer Engineering, Tufts University, Medford, USA, International Journal of Computer Science & Engineering Survey (IJCSES) Vol.3, No.6.