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Inter carrier Interference and Bit Error Rate of Various Pulse Shaping Functions Used in OFDM Communication Systems with

Dr.J.Kaliappan
Professor, Department of ECE
Sri Sai Institute of Technology and Science, Rayachoti
Email: kaliappanphd@gmail.com

Random Residual Carrier Frequency Offset ***Abstract***- **Rapid growth in the very large Scale Integration (VLSI) technology, embedded systems and Micro Electro Mechanical Systems (MEMS) has enabled production of less expensive sensor nodes which can be used for communication purposes with efficient use of their energy. Wireless Sensor networks can be deployed in various applications namely environmental monitoring e.g. volcano detection, distributed control system, detection of radioactive sources, agricultural and farm practices, internet, military and surveillance. The power analysis is a critical step in the sensor network development process. Recent advances in wireless sensor networks have led to many new Routing protocols specifically designed for sensor networks where energy awareness is an essential consideration. This paper presents a review of the main routing protocols proposed for wireless sensor networks.**

Keywords: **Sensor networks, Design issues, Routing protocols,Applications.**

1. INTRODUCTION

A wireless sensor network (WSN) as shown in fig.1 generally consists of a base station (or "gateway") that can communicate with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection.

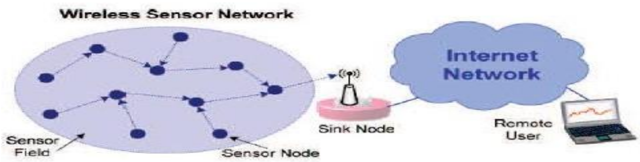

Fig-1 Wireless Sensor Networks

Each sensor device node as shown in fig.2 which communicate wirelessly in a wireless sensor network often consists of processing capability achieved by one or more microcontrollers, CPUs or DSP chips, may contain multiple types of memory such as program, data and flash memories, have a RF transceiver which is usually with a single omni directional antenna, have a power source e.g., batteries and solar cells. The sensor device is responsible for measuring physiological signals, processing the measured data, and then sending the measured data to a specific device wirelessly. Fig.3 shows the function of each sensor device component.

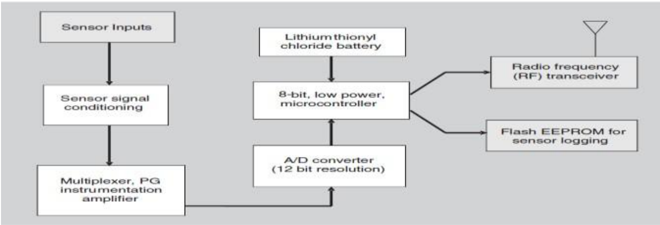

Fig. 2 Wireless sensor node functional block diagram

Name	Description
Processor	The interpretation of both locally sensed data and communication information are duties of processor. Usually, the processors are often limited in terms of computational power (e.g., many of the devices have only an eight-bit 16-MHz processor).
Memory	These devices have two kinds of memories: RAM and ROM which are used for instructions execution by the processor and storing raw and processed sensor measurements as well as other local information.
Radio Transceiver	WSN devices include a low-rate and short-range wireless radio (10–100 kbps, <100 m).
Sensor(s)	These devices may use of several sensors (such as temperature sensors, light sensors, humidity sensors …) depends on application to sense the environment.
Power Source	It provides the energy for the other components to work.
Geo-Positioning System	In many WSN applications, it is important for all sensors to know about their locations. This can be achieved, when the network is deployed in an ad hoc manner, via satellite-based GPS. Consider that, it may be an optional component because in some areas satellite access is not possible.

Fig. 3 Sensor Device Components

II. NETWORK CHARACTERISTICS AND DESIGNOBJECTIVES

The characteristics of sensor networks and application requirements have a decisive impact on the network design objectives in term of network capabilities and network performance [1].

A. NETWORK CHARACTERISTICS

Wireless sensor networks have the following unique characteristics and constraints:

- *Dense sensor node deployment, Battery-powered sensor nodes, Severe energy, computation, and storage constraints, Self-configurable, Unreliable sensor nodes,* *Data redundancy, Application specific, Many-to-one traffic pattern, Frequent topology change*

B. NETWORK DESIGN OBJECTIVES

All or part of the following main design objectives is considered in the design of sensor networks:

- *Small node size, Low node cost, Low power consumption, Scalability, Reliability, Self- configurability, Adaptability, Channel utilization, Fault tolerance, Security, QoS support.*

III. NETWORK DESIGN CHALLENGES AND ROUTING ISSUES

The design challenges in sensor networks involve the following main aspects:

- *Limited energy capacity, Sensor locations, Limited hardware resources, Massive and random node deployment, Network characteristics and unreliable environment, Data Aggregation, Diverse sensing application requirements, Scalability.*

IV. ROUTING IN WIRELESS SENSOR NETWORKS Routing in wireless sensor networks differs

from

conventional routing in fixed networks in various ways. Many routing algorithms were developed for wireless networks in general.

❖ *CLASSIFICATION OF ROUTING PROTOCOLS*

Fig.4 gives an overview of the routing taxonomy and Table I gives classification for different Routingprotocol.

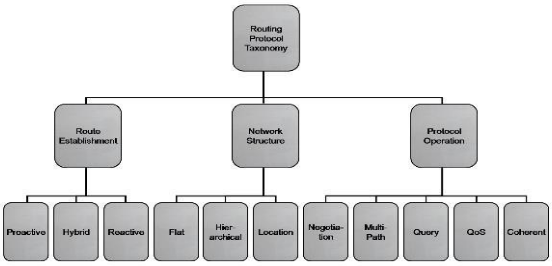

Fig. 4 Taxonomy of Routing Protocol

TABLE-I

Category	Representative Protocols
Data-centric or Flat Protocols	Flooding and Gossiping, SPIN, Directed Diffusion, Energy-aware routing, Rumor Routing, Gradient-Based Routing, CADR, COUGAR,ACQUIRE, EAD, Information Directed Routing, Quorum-Based Information Dissemination, Home Agent Based Information Dissemination, IDSQ,MCFA, Random Walks

Hierarchical Protocol	LEACH, E-LEACH, LEACHC, M-LEACH, LEACH-F, GPSR, PEGASIS, Hierarchical-PEGASIS, Energy Balancing PEGASIS, TEEN, APTEEN, Energy-Aware Routing, Self-organizing protocol, HEED, DECA, SOP, Sensor Aggregates Routing, VGA, HPAR, TTDD
Location-based Protocols	MECN, SMECN, GAF, GEAR, Greedy Approach (MFR, DIR, and GEDIR) , Compass routing, DREAM, GPSR, Coordination of Power Saving with Routing, TBF, BVGF, GeRaF
Multipath-based Protocols	Disjoint Paths, Braided Paths, N-to-1 Multipath Discovery
QoS-based Protocols	SAR, Energy-Aware QoS Routing Protocol, SPEED

A. ROUTE ESTABLISHMENT

Routing protocols can follow strategy that has a large impact on the performance and the lifetime of the network.

a. Reactive:

Reactive protocols try to establish a route between two nodes in the network if data has to be transmitted. Thus, they are usually the first choice for low data-rate networks with a dynamic topology since they do not generate any routing overhead in the absence of traffic.

b. Proactive:

Proactive routing protocols are most common in ad hoc and mesh networks since these networks have higher demands on the delay compared to WSNs. The protocols may provide an attractive alternative to reactive protocols.

c. Hybrid:

The majority of hybrid protocols can be divided into two groups. The first group does not transmit any routing information if no route is required. The second group of hybrid protocols uses proactive routing mechanisms for short range communication and reactive routing techniques for long range communication.

B. NETWORK STRUCTURE:

a. Flat or Data Centric:

Routing protocols which build a flat network structure represent the most applied type of protocols in WSNs.

1. Flooding and Gossiping:

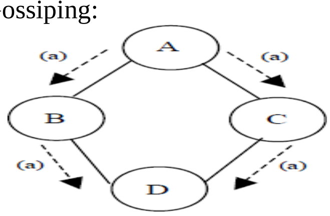

Fig.6: The implosion problem. Node A starts by flooding its data to all of its Neighbors. D gets two same copies of data eventually, which is not necessary.

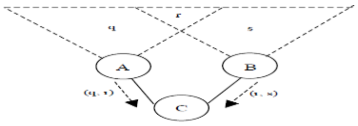

Fig.7 The overlap problem. Two sensors cover an overlapping geographicregion and C gets same copy of data from these sensors.

Flooding and Gossiping: In a flooding mechanism, each sensor receives a data packet and then broadcasts to all neighboring nodes. When the packet arrives at the destination or the maximum number of hops is reached, the process of broadcasting is stopped. However gossiping causes another problem which is delay in a propagation of data among sensor nodes.

2. Sensor Protocols for Information via Negotiation (SPIN):

The main idea in SPIN is to use Meta data instead of a full data packet transmitted at each node to all nodes.

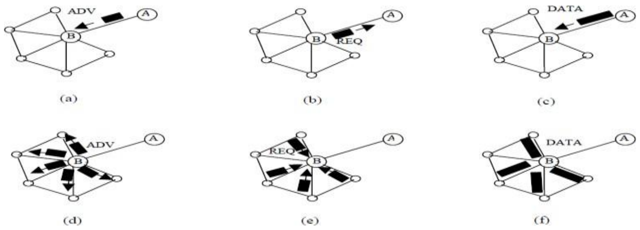

Fig.8 SPIN Protocol. Node A starts by advertising data to node B (a). Node B responds by sending a request to node A (b). After receiving the requesteddata (c). Node B then sends out advertisement to its neighbors (d). who in turn send requests back to B (e-f).

3. Directed Diffusion:

In Directed Diffusion idea aims at diffusing data through sensor nodes aims to use a scheme of naming data for all communications.

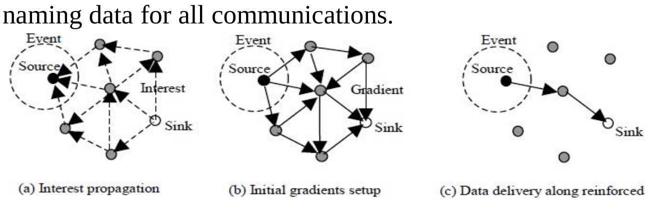

Fig.9 Directed Diffusion protocol phases

4. Energy-aware routing:

Shah and Rabaey routing proposed to use a set of sub-optimal paths occasionally to increase the lifetime of the network. There are 3 phases in the protocol:

i. Setup phase
ii. Data Communication Phase
iii. Route maintenance phase

5. Rumor routing:

Rumor routing is another variation of Directed Diffusion and is mainly intended for contexts in which geographic routing criteria are not applicable.

6. Gradient-Based Routing (GBR):

Schurgers and Srivastava idea is to keep the number of hops when the interest is diffused through the

network. Three different data spreading techniques havebeen presented:
• Stochastic Scheme
• Energy-based scheme
• Stream-based scheme

7. Constrained anisotropic diffusion routing (CADR):

CADR is a protocol, which strives to be a general form of Directed Diffusion. Two techniques namely information-driven sensor querying (IDSQ) and constrained anisotropic diffusion routing (CADR) are proposed.

8. COUGAR:

It views the network as a huge distributed database system. The main idea is to use declarative queries in order to abstract query processing from the network layer functions such as selection of relevant sensors etc. and utilizein-network data aggregation to save energy.

9. ACQUIRE:

A fairly new data-centric mechanism for querying sensor networks is Active Query forwarding in sensor networks (ACQUIRE). ACQUIRE mechanism provides efficient querying methods.

10. Information-Driven Sensor Query (IDSQ):

IDSQ addresses the problem of heterogeneous WSN of maximizing information gain and minimizing detection latency and energy consumption for target localization and tracking through dynamic sensor querying and data routing.

11. Minimum Cost Forwarding Algorithm (MCFA):

The MCFA algorithm [12] exploits the fact that the direction of routing is always known, that is, towards the fixed external base-station. Hence, a sensor node need not have a unique ID nor maintain a routing table.

12. Routing Protocols with Random Walks:

The objective of random walks based routing technique is to achieve load balancing in a statistical sense and by making use of multi-path routing in WSN.

b. Hierarchical:

Hierarchical protocols are highly scalable.

1. Low-Energy Adaptive Clustering Hierarchy (LEACH):

Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. The node becomes a cluster head for the current round if the number is less than the following threshold:

$$T(n) = \begin{cases} \frac{p}{1 - p * (r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

2. Enhanced Low-Energy Adaptive Clustering Hierarchy(E-LEACH):

E-LEACH further improved LEACH in two major aspects. E-LEACH proposes a cluster head selection algorithm for sensor networks that have non-uniform starting energy level among the sensors. E-LEACH also determines that, under certain assumptions, the required number of cluster heads has to scale as the square root of the total number of sensor nodes to minimize the total energy consumption.

3. LEACH-Centralized (LEACHC):

LEACH-C uses a centralized clustering algorithm and steady-state protocol. During the set-up phase of LEACH-C, each node sends information about current location and energy level to base station (BS). The BS will determine clusters, CH node and non-CH nodes of each cluster.

4. Multi-hop LEACH (M-LEACH):

M-LEACH modifies LEACH allowing sensor nodes to use multi-hop communication within the cluster in order to increase the energy efficiency of the protocol. Other works define special nodes (called gateways) that are able to send the information generated inside the cluster directly to the sink.

5. LEACH with Fixed Cluster (LEACH-F):

LEACH-F is the further development of LEACH, which is based on clusters that are formed once and then fixed. Then, the cluster head position rotates among the nodes within the cluster.

6. Greedy Perimeter Stateless Routing (GPSR):

The GPSR is a routing protocol to transfer the data packets in wireless datagram networks. GPSR is based on an algorithm which combines Greedy Packet Forwarding and Perimeter Forwarding methods.

7. PEGASIS:

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is an improvement of the LEACH protocol. Rather than forming multiple clusters, PEGASIS forms chains from sensor nodes so that each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink).

solution to the data gathering problem by consideringenergy* delay metric.

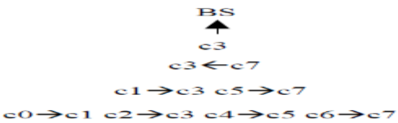

Fig.11 Data gathering in a chain basedBinary scheme.

9. Energy Balancing PEGASIS (EB-PEGASIS):

EBPEGASIS is an energy efficient chaining algorithm in which a node will consider average distance of formed chain.

10. TEEN:

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) is a hierarchical protocol designedto be responsive to sudden changes in the sensed attributes such as temperature.

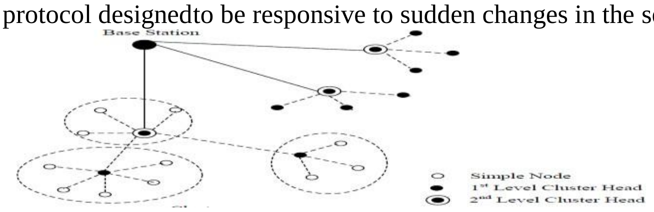

Fig.12 Hierarchial Clustering in TEEN & APTEEN

11. APTEEN:

The **A**daptive **T**hreshold sensitive **E**nergy **E**fficient sensor **N**etwork protocol (APTEEN) [8] is an extension to TEEN and aims at both capturing periodic data collections and reacting to time-critical events.

12. Energy-Aware Routing for cluster-based sensornetworks:

The author has proposed a different hierarchical routing algorithm based on three-tier architecture. Sensors are grouped into clusters prior to network operation. Gateways maintain the states of the sensors and sets up multi-hop routes for collecting sensors' data.

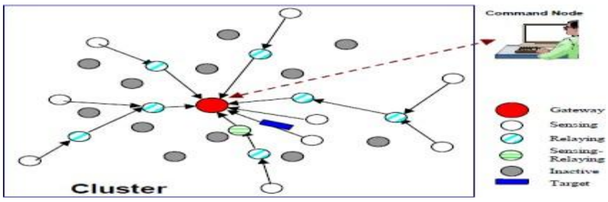

Fig.13: A Typical Cluster in a Sensor Network

13. Self-organizing protocol:

Subramanian et al. not only describe a self- organizing protocol but develop taxonomy of sensor applications as well. The algorithm for self organizing the router nodes and creating the routing tables consists of four phases:

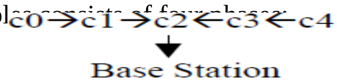

Fig.10: Chaining in PEGASIS

- Discovery phase,
- Organization phase,
- Maintenance phase,

8. Hierarchical-PEGASIS:

Hierarchical-PEGASIS is an extension to PEGASIS, which aims at decreasing the delay incurred for packets during transmission to the base station and proposes a

Self-reorganization phase.

The proposed algorithm utilizes the router nodes tokeep all the sensors connected by forming a dominating set.

14. Hybrid, Energy-Efficient Distributed Clustering (HEED):

HEED was proposed with four primary goalsnamely (i) prolonging network lifetime by distributing energy consumption, (ii) terminating the clustering process within a constant number of iterations, (iii) minimizing control overhead, and (iv) producing well-distributed CHs and compact clusters.

15. DECA:

DECA is an improved **D**istributed **E**fficient **C**lustering **A**pproach. The phases involved in DECA operations are: *Start Clustering, Receive Clustering Message,Actual announcement, Finalize Clustering.*

16. Self Organizing Protocol (SOP):

Subramanian et al. describes a self-organizing protocol and an application taxonomy that was used to build architecture used to support heterogeneous sensors.

c. Location-based Routing:

1. Minimum Energy Communication Network (MECN):

By using low power GPS devices, sensor nodes in MECN can setup and maintain a minimum energy network.

2. Small MECN (SMECN):

In SMECN that node could be fully connected, the sub-network established in SMECN for minimum energy is smaller in terms of the number of edges compared with the one in MECH if broadcasts are able to reach all nodes in a circular region around the broadcaster.

3. Geographic Adaptive Fidelity (GAF):

It is a GPS location-based routing algorithmdesigned primarily for mobile ad-hoc network.

4. Geographic and Energy Aware Routing (GEAR):

GEAR uses of geographic information and relays queries to certain regions because data queries contain geographic attributes.

5. Greedy approach:

In I. Stojmenovic et al. stated that the neighboring node Y which is closer to the destination node D from the source or intermediate node S conducts the packet to the destination. The data flows through the intermediate nodes like this until it reaches the destination node D.

Fig.14: Implementation of Greedy approach in WSN

6. Compass routing:

In E.Kranakis et.al stated that the source node S calculates the direction of the destination D and the neighboring node Y which is having closest direction to the destination than SD is selected as the next eligible intermediate node to route the data from the source node.

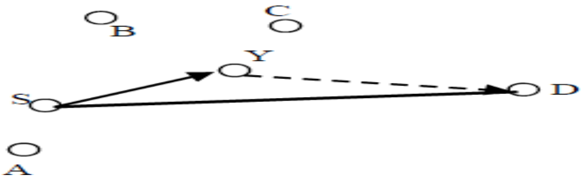

Fig.15: Compass routing approach in WSN

7. A distance Routing Effect Algorithm for Mobility[DREAM]:

In S. Basangi proposed the model of flooding packets to all the neighboring nodes of node x, here a different approach was taken. The data is only flooded to the limited number of nodes which is coming under the area when the tangents are flowing between the node x to the circle centered at destination D.

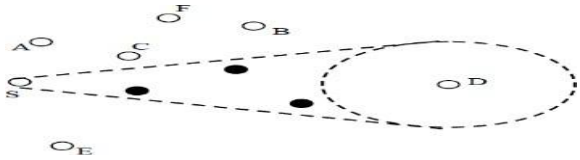

Fig. 16: Routing structure in DREAM protocol

8. Greedy Perimeter Stateless Routing [GPSR]:

The modified version of greedy-face-greedy algorithm is the Greedy perimeter stateless routing.

9. Coordination of Power Saving with Routing [SPAN]:

Span is a routing protocol also primarily proposed for MANET, but can be applied to WSNs as its goal is to reduce energy consumption of the nodes.

10. Trajectory-Based Forwarding (TBF):

TBF is a routing protocol that requires a sufficiently dense network and the presence of a coordinate system.

11. Bounded Voronoi Greedy Forwarding [BVGF]:

BVGF uses the concept of Voronoi diagram in which the sensors should be aware of their geographicalpositions.

12. Geographic Random Forwarding (GeRaF):

GeRaF was proposed by Zorzi and Rao which uses geographic routing where a sensor acting as relay is notknown a priori by a sender.

C. PROTOCOL OPERATION

a. Negotiation-based Routing:

Negotiation-based routing protocols directly address the problem of duplicate data transmission by using high-level data descriptors.

b. Multi-Path:

Multi-path routing protocols are often used to increase the fault tolerance of wireless networks with unreliable data links.

c. Query-based Routing:

A WSN can be regarded as a large distributed data base in which each node holds a small part of the overall information. This point of view has led to a new group of routing protocols which are based on queries.

d. Quality of Service Support:

In addition to minimizing energy consumption, it is also important to consider quality of service (QoS) requirements in terms of delay, reliability, and fault tolerancein routing in WSNs.

V. COMPARISON OF ROUTING PROTOCOLS IN WSN:

Routing Protocols	Classification	Power Usage	Data Aggregation	Scala bility	Query Based	Over head	Data delivery model	QoS
SPIN	Flat / Src-initiated / Data-centric	Ltd.	Yes	Ltd	Yes	Low	Event driven	No
DD	Flat/ Data-centric/ Dst-initiated	Ltd	Yes	Ltd	Yes	Low	Demand driven	No
RR	Flat	Low	Yes	Good	Yes	Low	Demand driven	No
GBR	Flat	Low	Yes	Ltd	Yes	Low	Hybrid	No
CADR	Flat	Ltd		Ltd	Yes	Low	Continuously	No
COUGAR	Flat	Ltd	Yes	Ltd	Yes	High	Query driven	No
ACQUIR E	Flat/ Data-centric	Low	Yes	Ltd	Yes	Low	Complex query	No
LEACH	Hierarchical / Dst-initiated /Node-centric	High	Yes	Good	No	High	Cluster-head	No
TEEN & APTEEN	Hierarchical	High	Yes	Good	No	High	Active threshold	No
PEGASIS	Hierarchical	Max	No	Good	No	Low	Chains based	No
VGA	Hierarchical	Low	Yes	Good	No	High	Good	No
SOP	Hierarchical	Low	No	Good	No	High	Continuously	No
GAF	Hierarchical / Location	Ltd	No	Good	No	Mod	Virtual grid	No
SPAN	Hierarchical / Location	Ltd	Yes	Ltd	No	High	Continuously	No
GEAR	Location	Ltd	No	Ltd	No	Mod	Demand driven	No
SAR	Data centric	High	Yes	Ltd	Yes	High	Continuously	Yes
SPEED	Location/Data centric	Low	No	Ltd	Yes	Less	Geographic	Yes

CONCLUSION:

All the protocol & algorithms available so far in this area, has certain limitations in Energy consumption, Data aggregation, scalability and Quality of service of the Sensor Nodes. In this review paper, various existing techniques in the area of routing protocol of wireless sensor is covered to give wider choice to researchers to understand the limitation of sensor networks.

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