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Cluster Wireless Sensor Networks for Safe and Efficient Transmission

P.Susmitha Vani, Praky Jain, Jyothi B

Student, Dr. Ambedkar Institute of Technology, susmita.vani@gmail.com, 9740877064

Abstract— Wireless Sensor Networks is one of the most rapidly growing and emerging concept in the scientific domain. It is growing because of its low cost and wide applications. WSN is one of communication tools used in many areas such as in civilians and militaries. WSN is a wireless network consisting of a web of sensor nodes whose basic feature is to sense, compute, communicate and power. Storage, bandwidth, communication capability, limited energy is its main resource constraints. Secure data transmission is an important issue for WSNs. Clustering is a way of enhancing the system performance of WSNs. In this paper, by using the concept of IBS and IBOOS scheme, we study SET protocols for CWSNs, called SET-IBS and SET-IBOOS. SET-IBS depends on the Diffie-Hellman problem. SET-IBOOS relies on discrete logarithm problem and the overhead computation for protocol security is reduced, which is crucial for WSNs. Our survey is based on various aspects of wireless sensor networks, discussing various types of WSNs and their applications, different distributed clustering algorithms used in WSNs and the reliability of routing protocols.

Keywords— WSN, Cluster-based WSNs, SET protocols, IBS/IBOOS schemes, Sensor nodes, Routing protocols, Diffie-Hellman problem, Discrete logarithm problem.

INTRODUCTION

A Wireless sensor network (WSN) is a network system comprised of spatially distributed devices using wireless sensor nodes which are used to monitor physical or environmental conditions, such as temperature, motion and sound. The individual nodes sense their environments, process the information data locally, and send data to one or more collection points in a WSN [1].

Efficient data transmission is one of the most important issues for WSNs. WSNs are deployed in rough, disregarded, and physical environments for certain applications. Sensor networks advantages are reliability, robustness, accuracy, and fault tolerance. Data dissemination and Data gathering are important WSN operations [2]. Secure and efficient data transmission (SET) is necessary and demanded in many such practical WSNs.

The basic step of working of WSN: Sensing-> Computation->Communication->Data aggregation at sink node->various applications.

Limited power sources and cost effectiveness of sensors to recharge the batteries which are usually irreplaceable so, their lifetime will depend on sensor batteries. The life time of wireless sensor network can be prolonged by using effective energy balancing methods.

ASPECTS OF WSN

Characteristics of WSN:

The main characteristics of WSN are:

- It uses Data centric approach
- Efficient power management
- Uses broadcast communication approach to gather information
- Withstanding harsh environments
- Cheap sensor nodes and easy to use

- Use of various protocols for efficient energy consumption.
- Heterogeneity and mobility of nodes i.e. nodes are not fixed.
- Cross layer design to improve transmission performance.

WSN Architecture

WSN architecture includes both a hardware platform and operating system designed. TinyOS [3] is a component based operating system designed to run in resource constraint wireless device.

The major components of WSN are:-

- Sensor Field: The area in which sensor nodes are deployed.
- Sensor Nodes: Sensor nodes are the sensors which are responsible for gather information and routing this information back to a sink.
- Sink: It is also a sensor node which receives, processes and stores data from other sensor nodes. It is responsible for message reduction need to be sent and also reduce the energy requirements.
- Task Manager (Base Station): a centralized point of control within the network used to extract information from the network and passes control information back to the network.

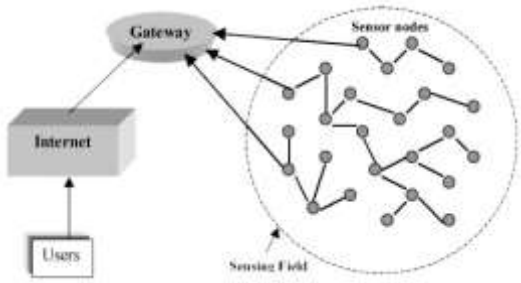

Fig1: Components of WSN

A Sensor is a tiny monitoring device which is based on micro sensor technologies which are capable of processing, sensing and communicating with other nodes. Signal processing capability is low with low computation power and bandwidth.

Components of wireless sensor node:

- Sensor Unit
- Processing Unit
- Radio Transreceiver
- Battery
- Analog to Digital Convertor
- Location Finder
- Mobilizer

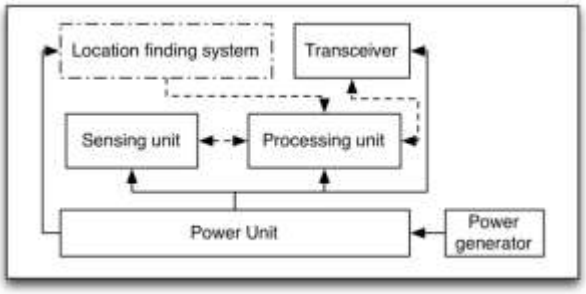

Fig2: Components of sensor node

TYPES OF WSN AND ITS APPLICATION

On the basis of interfaces sensor networks are classified in which nodes are deployed:

Underwater Wireless sensor network:

In this sensor network sensor nodes are employed under water. Through acoustic waves sensor nodes communicate with each other. This type is expensive, sparsely used, typically communicating directly to a base-station over long ranges rather than with each other [4]. This has limited bandwidth, long propagation delay and signal fading problem.

Applications: -

- Seismic monitoring
- Equipment Monitoring and Control

Underground Wireless sensor network:

This network is basically established under the ground and used to monitor the underground situations which are carried out through electromagnetic waves. Its disadvantages include signal loses and high attenuation and expensive.

Applications:

- Earthquake and landslide monitoring
- Intruder detection
- Environment monitoring
- Assisted navigation
- Infrastructure maintenance
- Sports field maintenance

Earthbound Wireless sensor network:

It is terrestrial WSNs where of nodes are arranged in ad hoc approach. Placements of nodes can be of optimal, grid, 2D, 3D types.

Applications:

- Military applications
- Environmental Monitoring
- Security
- Node tracking system
- Medical applications
- Industrial application
- Monitoring of human physiological data
- Forecasting

Mobile Wireless Sensor Network:

In this type of network sensor nodes are deployed to gather the information. These nodes can reposition and organize themselves in network .Localization, coverage, energy, maintenance, data processing etc are main features of mobile WSNs.

Applications:

- Heart rate, blood pressure health monitoring [5].
- Sensors attached to animals to track their migration patterns, feeding habits 6].
- Attaching sensors to aerial vehicles (UAVs) for surveillance and mapping [7].

Multi-media Wireless sensor networks:

These networks consist of a number of low cost sensors equipped with cameras and microphones which are used to monitor and track events in the form of multimedia. Its features include high bandwidth with low energy, QoS, filtering, processing data and its compression techniques.

Applications:

- Traffic monitoring
- Pollution control
- Smart healthcare
- Disaster/Emergency response
- Smart Environmental sensing

Wireless Nano sensor network:

Wireless communications is done based on integrated machines at the nano scale. For accelerating the deployment process of nano technology the design for the wireless nano sensor networks is fundamental.

CLUSTERING ALGORITHMS

Grouping of sensor nodes into clusters is called clustering. Every cluster has a leader, referred to as cluster-head (CH). The sensor nodes in the cluster or pre-assigned by the network designer elect CH [9]. A CH is a sensor or a node that is generally richer in resources. Membership of the cluster may be fixed or variable.

Advantages:

- Supports network scalability and localization of the route setup in the cluster [10].
- Conserves communication bandwidth [11].
- Stabilizes the network topology at the level of sensors and cuts on topology maintenance overhead [12].
- Implementation of optimized management strategies to prolong the battery life [13].

A CH can schedule activities in the cluster so that the nodes can switch to the low-power sleep mode most of the time and reduce the rate of energy consumption.CH aggregates the data collected by the sensors in its cluster [14].

Distributed clustering algorithms for WSNs

Distributed clustering is the mechanism in which, there is no fixed central CH and the CH keeps on changing from node to node based on some pre-assigned parameters.

A. Low Energy Adaptive Clustering Hierarchy (LEACH):

LEACH [15] is a clustering mechanism that distributes energy consumption all along its network which is divided into clusters. CHs are purely distributed and randomly elected. CHs collect the information from the nodes under its cluster. LEACH protocol involves four main steps for each round: Advertisement phase, cluster set-up phase, schedule creation and data transmission. Distinct CDMA codes are used to deal with Multi-cluster interference problem.

B. Hybrid Energy-Efficient Distributed Clustering (HEED):

HEED [16] is a distributed algorithm which selects the CH based on both residual energy and communication cost and supports heterogeneous sensor nodes. The random selection of CH and uneven distribution among the CH nodes will have its effect on the data gathering. Three phases in HEED protocol: Initialization, repetition and finalization phase.

C. Energy Efficient Hierarchical Clustering (EEHC):

EEHC [17] is a distributed, randomized clustering algorithm for WSNs. Information about the individual clusters is collected by CH and sends the report to the base-station. Their technique has two stages: Initial and extended. The initial stage is single-level clustering. Each sensor node declares itself as a volunteer CH. The second stage, is multi-level clustering and generally builds h levels of cluster hierarchy. To form an additional tier the clustering process is recursively repeated. The algorithm ensures h-hop connection between the base-station and cluster head.

D. Linked Cluster Algorithm (LCA):

The Linked Cluster Algorithm (LCA) is a distributed clustering algorithm that avoids communication collisions among nodes and uses TDMA frames for inter-node communication, with each node has a frame having a slot in the network for communication. It focuses on single-hop clustering and guarantees that no node will be more than one hop away from leader.

E. CLUBS:

This algorithm uses the advantage of local communication to efficiently aggregate the nodes into clusters [18]. Every node must belong to some cluster of same diameter in the network. It should have local routing, which means that every node within the cluster should be able to communicate with each other using only nodes within that same cluster. The CLUBS algorithm forms overlapping clusters. The main advantage of CLUBS is that CH conflict is probabilistically lower.

F. Fast Local Clustering Service (FLOC):

FLOC [19] is a distributed clustering technique that produces non-overlapping equal-sized clusters. FLOC achieves locality. FLOC exhibits a double-band nature of wireless radio-model for communication. A node can communicate reliably with the nodes that are in the inner band (i-band) range and unreliably with the nodes in its outer-band (o-band) range.

G. Algorithm for Cluster Establishment (ACE):

ACE [20] is a highly uniform cluster formation, self-organizing, efficient coverage, lesser overlapping and emergent cluster forming algorithm for WSNs, which is scale-independent No knowledge of geographic location is required. The main idea of ACE is to assess the potential of a cluster node as a CH before becoming a CH and steps down if it is not the best CH at the moment. The two logical steps in ACE algorithm is “spawning” of new clusters and “migration” of existing clusters. ACE exhibits perfect scalability. ACE is fast, robust against packet loss and node failure thereby efficient in terms of communication.

H. DWEHC:

Distributed Weight-Based Energy-Efficient Hierarchical Clustering [21] is a well distributed clustering algorithm, which generates well balanced clusters. Each node first locates its neighbours, and then calculates its weight which is based on its residual energy and distance to its neighbors. The largest weight node in a neighborhood may become a CH. Neighboring nodes will join the clustered hierarchy as member nodes. There is significant improvement in both intra-cluster and inter-cluster energy consumption .

ROUTING PROTOCOLS

The process of determining a path between the source node and the destination node upon request of data transmission is called routing. Packets are relayed by nodes with the help of routing. For any given packet destination the routing tables contain lists of node options.

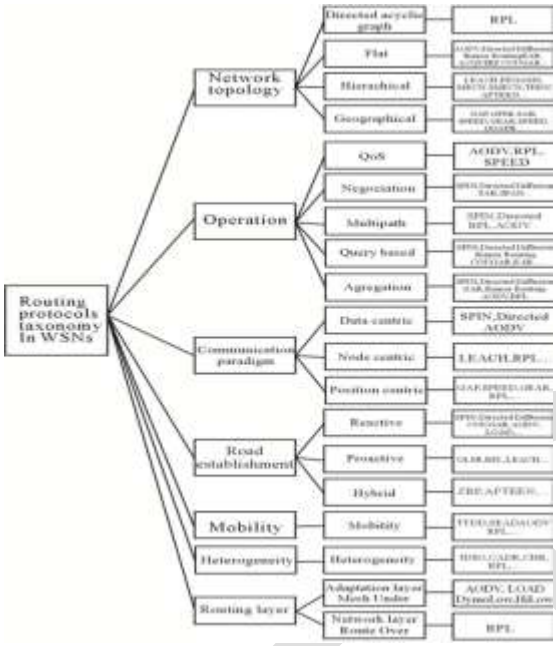

Fig3: Different Routing Protocols

WSN Routing Protocols can be classified into five ways:

- Establishment of the routing paths
- network structure
- protocol operation
- initiator of communications
- Selection of next-hop on the route of the forwarded message by a protocol

Path establishment Based Routing Protocols:

Routing paths can be established in one of three ways:

- Proactive: computes all the routes before they are really needed and then store these routes in a routing table in each node.
- Reactive: compute all the routes before they are really needed and then store these routes in a routing table in each node. They do not maintain the global information of all the nodes in a network.
- Hybrid: uses a combination of both proactive and reactive routing strategies which is applied to large networks.

Network Based Routing Protocols:

According to the structure of network and their functionalities protocols are divided into 3 categories:

- Flat-Based Routing: The number of sensor nodes is very large and uses data-centric routing approach in which Base station sends query to a group of particular nodes in a region and waits for response.

Examples of Flat-based routing protocols are:

- ✓ Energy Aware Routing (EAR)
- ✓ Directed Diffusion (DD)
- ✓ Sequential Assignment Routing (SAR)
- ✓ Minimum Cost Forwarding Algorithm (MCFA)
- ✓ Sensor Protocols for Information via Negotiation (SPIN)
- ✓ Active Query forwarding In sensor network (ACQUIRE)

- Hierarchical-Based Routing:

  Also called as cluster based routing, it is used for network scalability and efficient communication. Hierarchical-based routing is energy efficient method in which high energy nodes are randomly selected for processing and sending data while low energy nodes are used for sensing and send information to the cluster heads.

  Examples of hierarchical-based routing protocols are:

  - ✓ Hierarchical Power-Active Routing (HPAR)
  - ✓ Threshold sensitive energy efficient sensor network protocol (TEEN)
  - ✓ Power efficient gathering in sensor information systems.
  - ✓ Minimum energy communication network (MECN)

- Location-Based Routing:

  Sensor nodes are scattered which are located using GPS.

  Examples of location-based routing networks are:

  - ✓ Sequential assignment routing (SAR)
  - ✓ Ad-hoc positioning system (APS)
  - ✓ Geographic adaptive fidelity (GAP)
  - ✓ Greedy other adaptive face routing (GOAFR)
  - ✓ Geographic and energy aware routing (GEAR)
  - ✓ Geographic distance routing (GEDIR).

Operation Based Routing Protocols:

Optimal performance is achieved and the resources of the network are conserved. These routing protocols are classified according to their operations:

- Multipath Routing Protocols:

  Multiple path selection for a message is done to reach destination thereby decreasing delay and increasing network performance.

  Multipath routing protocols are:

  - ✓ Multi path and Multi SPEED (MMSPEED)
  - ✓ Sensor Protocols for Information via Negotiation (SPIN)

- Query Based Routing Protocols:

  Queries are sent and received for data using high level languages. The destination node sends query of interest from a node through network and node with this interest matches the query and send back to the node which initiated the query.

  Query based routing protocols are:

  - ✓ Sensor Protocols for Information via Negotiation (SPIN)
  - ✓ Directed Diffusion (DD)
  - ✓ COUGAR.

- Negotiation Based Routing Protocols:

High level data descriptors are used to eliminate redundant data transmission through negotiation. Intelligent decisions are made either for communication or other actions based on facts such that how much resources are available. Negotiation based routing protocols are:

- ✓ Sensor Protocols for Information via Negotiation (SPAN)
- ✓ Sequential assignment routing (SAR)
- ✓ Directed Diffusion (DD)

- QoS Based Routing Protocols:

  Network needs to have a balance approach for the QoS of applications. To achieve QoS, the cost function for the desired QoS also needs to be considered.

  Examples of QoS routing are:

  - ✓ Sequential assignment routing (SAR)
  - ✓ SPEED
  - ✓ Multi path and Multi SPEED (MMSPEED)

Initiator of Communication Based Routing Protocol:

Communication between a network components is done, where they usually in sleep mode temporary. The source node initiates the routing with other part to send or/and receive the control or data packets for service.

- Source Initiator Routing Protocol
- Destination Initiator Routing Protocol

Next-Hop Selection Based Routing Protocols:

- Content-based routing protocols:

  Based on the query content the next-hop on the route is determined. The base requests only for data regardless of its origin and does not query.

- Probabilistic routing protocols:

  Sensor nodes are homogeneous and randomly deployed. They select the next-hop neighbour for the message to be forwarded.

Energy Aware Routing Protocol:

- Location-based routing protocols:

  The next-hop towards the destination is selected based on the known position of the neighbors and the destination.Communication overhead caused by flooding can be avoided.

  - ✓ GEAR (Geographical and Energy Aware Routing).

- Hierarchical-based routing protocols:

  Message for a each node (also called aggregator) that is in a higher hierarchy level than the sender is forwarded. The incoming data is aggregated in each node by which communication overload is reduced and energy is conserved. Network lifetime and scalability is increased. The set of nodes which forward to the same aggregator(CH) is called cluster.

  - ✓ LEACH (Low Energy Adaptive Clustering Hierarchy) protocol.

- Broadcast-based routing protocols:

  Each node in the network decides individually whether to forward a message or not. If a node decides to forward, it simply re-broadcasts the message. If it declines to forward, the message will be dropped.

  - ✓ MCFA (Minimal Cost Forwarding Algorithm).

SET-IBS and SET-IBOOS Protocols:

Two Safe and Efficient for CWSNs, called SET-IBS and SET-IBOOS is used. The idea of both protocols is to check the validity of the encrypted sensed data. Digital signatures and key management are applied to message packets for verification and security. The Base Station distributes secret keys and pairing parameters and loaded in all the sensor nodes which deals with the key escrow problem described in ID-based cryptosystems. Safe communication in relies on the ID based cryptography is used in SET-IBS for secure communication. User public keys are their ID information. To reduce the computational overhead for security the IBOOS scheme is used, in which security relies on the hardness of the discrete logarithmic problem. Both protocols solve the orphan node problem using the concept of symmetric key management. It requires less energy for computation and storage. The CH sensor nodes execute the offline signature.Node to node communication is more suitable using SET_IBOOS in CWSNs.

CONCLUSION

In this paper, we first reviewed the aspects of wireless sensor networks, its characteristic and architecture. We also discussed various types of WSNs and their applications. We then presented different types of clustering mechanisms stating their advantages and disadvantages. We classified the routing protocols into many categories and stated two secure and efficient data transmission protocols for CWSNs i.e. SET-IBS, and SET-IBOOS. These can provide us solutions for many monitoring problems. We can conclude that to make the Wireless sensor network energy efficient is one of the great areas for future work.

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