Network Topologies in Wireless Sensor Networks: A Review

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Abstract
In Wireless Sensor Networks (WSNs), sensor nodes have limited battery power, so energy consumption is essential issue. Every sensor node can obtain its location information from GPS or other positioning system and send data to sink at any time. In this paper, comparison of the dynamic network topologies in Wireless Sensor Networks has been done. The characteristic of this is to divide WSN into network based on Topologies i.e. Bus, Tree, Star, Ring, Mesh, Circular, Grid. Information of the position of nodes, and those nodes are organized within the network by the Topological way.

Keywords
Data Gathering, Dynamic Network Topologies, Energy-Balanced Routing, Packet Reception Ratio, Wireless Sensor Network

I. Introduction

Wireless Sensor Networks (WSNs) is an emerging technology with a wide range of potential applications such as patient monitoring systems, earthquake detection, environment monitoring, military applications (such as navigation, surveillance, security and target tracking management) [1]. A wireless sensor networks is a collection of nodes organized into a cooperative network. Sensor networks spatially distributed autonomous sensors to monitor physical and environmental conditions at different locations, such as temperature, pressure, motion sound, vibration etc. For WSNs, many protocols have been specifically designed must be efficient, fast, resource friendly where energy awareness is an essential design issue. In wireless sensor networks, there are unique challenges with regards to unit power consumption, overall size and heat transfer. Formal verification is the process used to enable trust and security issues to be verified in relation to security protocol design for the information communications sector as shown in Fig. 1.1. WSNs typically consist of small, inexpensive, resource-constrained devices that communicate among each other using a multi-hop wireless network.

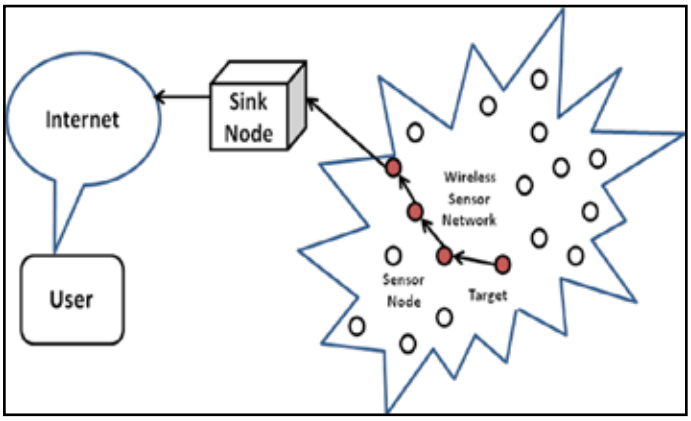

Fig. 1.1: Architecture of Wireless Sensor Network

Each node, called a sensor node, has one sensor, embedded processors, limited memory, low power radio and is normally battery operated. Each sensor node of the network is responsible for sensing an event locally which is desired and at end user event is reported which is for relaying a remote event sensed by other sensor nodes. Sensor has limited energy resources as battery- powered, and their functionality continues until their energy is finished and energy conversation is always a research focus in WSN. A node should not be switched to sleeping state when it is collecting data. To ensure this, the time of the node in working state should be longer than the time spent in collecting data. Therefore, applications and protocols for WSNs should be carefully designed in terms of energy-efficient manner so that the lifetime of sensor can be longer. The sensing element of a sensor probes the surrounding environment [2]. The components of sensor node are sensing unit, processing unit, transmission unit, power unit which are shown in the fig. 1.2.

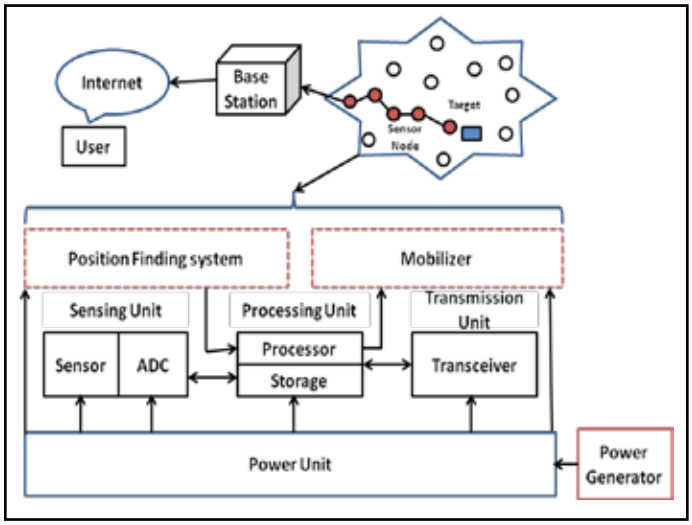

Fig. 1.2: Components of Sensor Node

The power saving modes of operation are sensor nodes communicate using shortest paths, the shorter the packets, the more dominance of startup energy, operation in a power saving mode is energy efficient in that case when the time spent in that mode is more than a certain threshold.

In wireless sensor networks, the following steps can be taken to save energy caused by communication are scheduling the state of the nodes. (i.e. transmitting, receiving, idle or sleep), change the transmission range between the sensing nodes, using data collecting methods and efficient routing, as in the case of overhearing avoid the unwanted data handling. If an interesting event is detected, after performing signal processing of the observed data, sensors communicate this data to the sink or base station using a radio based link [3]. This communication happens in a single or multi-hop fashion depending on the location of the sensing node and the node has to access the medium and then transmit the data. Thus, medium access control (MAC) protocol plays an essential role in WSN. As stated earlier, these MAC protocols should be energy efficient. Because mobile nodes have limited battery power, it is therefore very important to use energy in mobile ad hoc networks (MANETs) efficiently [4].

The rest of this paper is organized in sections as follows. In Section II surveys literature studies on Network Topologies in new directions. Section III presents comparison in between the topologies of WSN related to performance such as PRR and energy consumption, Finally, Section V presents future work.

II. Different Topologies

The development and deployment of WSNs have taken traditional network topologies in new directions. Different Wireless sensor network topologies are Bus, Tree, Star, Ring, Mesh, Circular and Grid.

A. Bus Topology

In this topology, there is a node send message to another node on the network sends a broadcast message onto the network that all other nodes see, but only the intended recipient actually accepts and processes the message. Bus topology is easy to install but congestion of traffic and single path communication. However, bus networks work best with a limited number of nodes. If more than a few dozen nodes are added to a network bus, performance problems will likely result.

Zhizhou et al.[5] improve the road network efficiency. This paper based on the analysis of the shortcomings of traditional technologies, including location technology, communication technology, the advantages of Wireless Sensor Network (WSN) and Zigbee are given first. Then the data requirements of Bus Priority Control System (BPCS) are presented.

Wanjing et al. [6], this paper presents a framework for real-time bus priority control system. The proposed system architecture integrated active and passive strategies and adding a priority classification level, can provide efficient bus priority control and minimize overall effects to motor vehicle movements under different traffic condition.

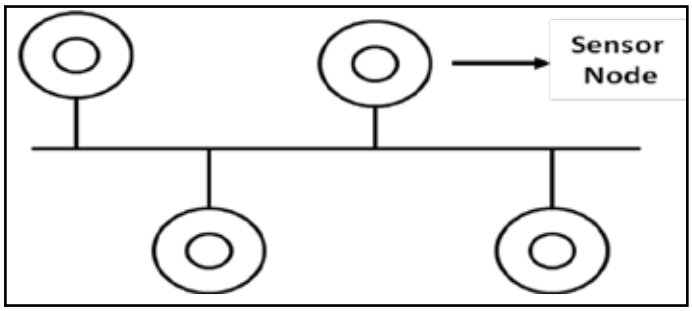

Fig. 2.1: Bus Topology

2. Tree Topology

The network use a central hub called a root node as the main communication router. In the hierarchy, central hub is one level below from the root node. This lower level forms a star network. The tree network can be considered a hybrid of both the Star and Peer to Peer networking topologies as shown in Fig 2.2. In sensor network path may be single hop or multi hop, sensor node for getting data sense the environment and sent them to the sink and sensor forwards them to its parent after receives data messages from its children. It is important to find an optimal shortest path tree with maximum lifetime and shorter delay but slightly high time complexity and but more suitable for distributed implementation. There is problem into the load balancing scheme at each level of the fat tree and there is communication in between two nodes. If there is a link break in the unipath on the active route then communication also breaks.

Le et al.[7] proposed an approach to construct a shortest path tree for each sink and dynamically adjust to balance the load among sinks. These works are based on real systems, but do not provide theoretical insight into maximization of lifetime.

Y. Wu et al.[8] considering the energy depletion in transmitting and receiving messages, which are the two major energy consuming operations.

Dijun et al.[9] studied the problem of finding an optimal shortest path tree to prolong the lifetime of the network, when in network aggregation is used.

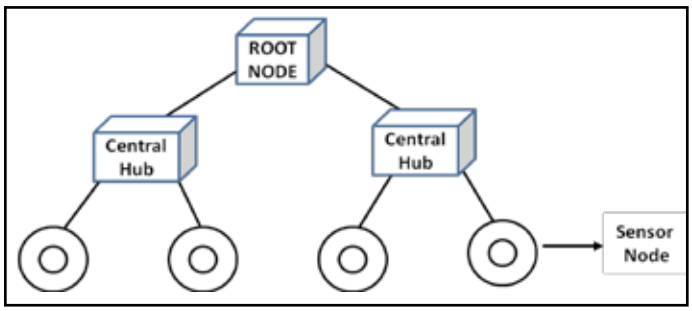

Fig. 2.2: Tree Topology

C. Star Topology

Star networks are connected to a centralized communication hub (sink) and the nodes cannot communicate directly with each other. The entire communication must be routed through the centralized hub. Each node is then a "client" while the central hub is the "server or sink" as shown in Fig. 2.3. But there is disadvantage of single path communication.

Yang et al.[10] proposed Turbo-Like (TL) codes with two simplified serial message passing algorithms for star- WSN. The two algorithms are implemented based on variable node updating. One is the modified sum-product algorithm (MSPA) and the other is the simplified feedback belief propagation algorithm (S-FBPA), both of proposed algorithms have significant complexity reduction.

Imad et al.[11] proposed a new routing method for WSNs to extend network lifetime using a combination of a fuzzy approach and an A-star algorithm. The proposal is to determine an optimal routing path from the source to the destination by favoring the highest remaining battery power, minimum number of hops, and minimum traffic loads. To demonstrate the effectiveness of the proposed method in terms of balancing energy consumption and maximization of network lifetime, we compare our approach with the A-star search algorithm and fuzzy approach using the same routing criteria in two different topographical areas.

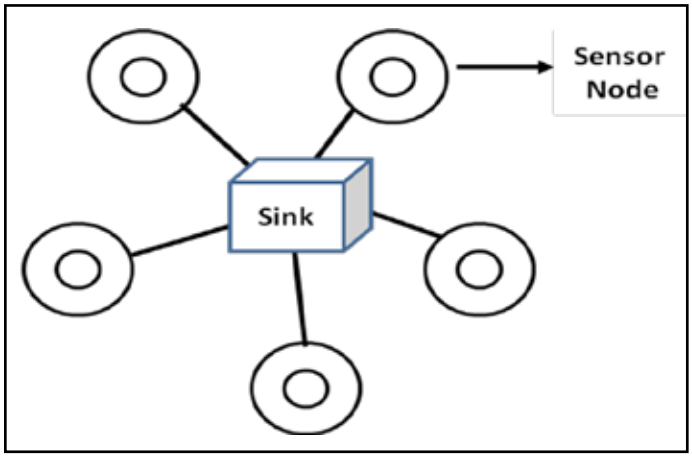

Fig. 2.3: Star Topology

D. Ring Topology

In a ring network, every node has exactly two neighbors for communication purposes. All messages travel through a ring in the same direction (either "clockwise" or "counterclockwise"). A failure in node breaks the loop and can take down the entire network. but congestion of traffic and double path communication.

A.S el al.[12] proposed two schemes for key management in

clustered sensor networks with changing cluster head. In Simple Secure Logical Ring (SSLR) scheme communication and computation cost incurred for key establishment is constant. Node compromise in the proposed schemes is handled efficiently.
Zhi et al.[13] proposed algorithm considers remaining energy when selecting cluster heads and uses multi-round clustering instead of clustering in every round. Algorithm performs better in reducing the energy consumption of nodes and effectively improves the lifetime of WSNs.

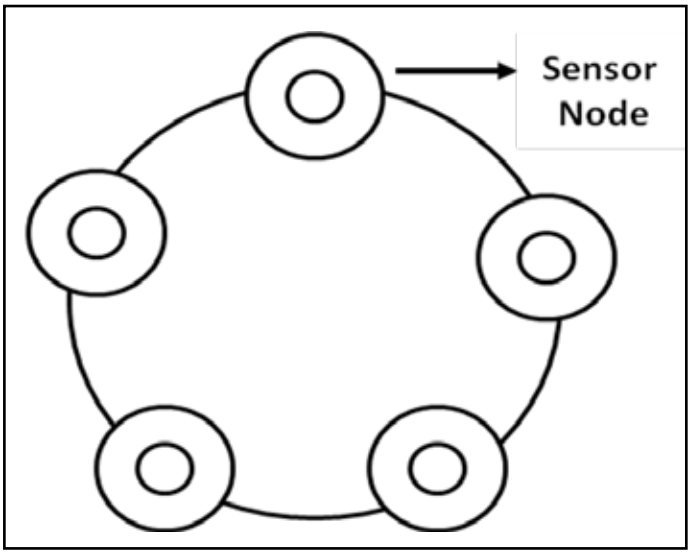

Fig. 2.4: Ring Topology

E. Mesh Topology

Mesh topologies involve message can take any of several paths from source to destination. (Recall that even in a ring, although two paths exist, messages can only travel in one direction.) A mesh network in which every node connects to every other is called a full mesh and there is partial mesh networks also exist in which some devices (nodes) connect only indirectly to others.
Riggio et al.[14] proposed an hybrid mesh/sensor network architecture based on a sharing of tasks between mesh routers and sensor nodes and reduce the network load while preserving data confidentiality and integrity.
Thuy et al.[15] proposed a multipath solution for event-driven cluster-based routing in WSN called Energy-Aware Mesh Routing Protocol (EMRP) with main design features: reliable data transmission, load balance and energy efficiency.

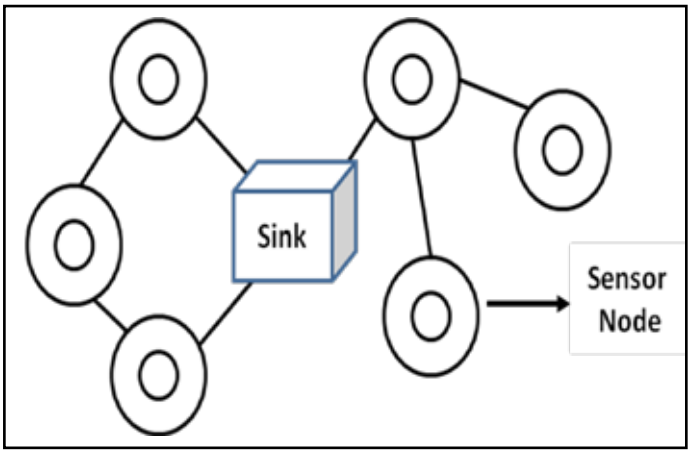

Fig. 2.5: Mesh Topology

F. Circular Topology

In this topology, there is a circular sensing area and that the sensing area has a sink (at center). The sensor nodes sense the event of interest and transmit these data to the sink. The nodes are randomly deployed with uniform density all around the sink as shown in Fig.2.6. Depending on the distance of a node from the sink and the transmission range of the nodes, data have to traverse single or multiple hops before being received by the sink. The circular web topology is easy to establish, easy to maintain, and more efficient [16].
Shanti et al.[17] in this DGRAM is fully self-configuring and slot assignment is done without exchange of any control messages. . It is energy efficient, nodes go through a short beacon exchange phase to learn the location of other nodes. Vijayalakshmi el al.[18] presents an integrated MAC and routing protocol for time sensitive WSN applications and TDMA-based protocol. At particular time slot only some of the nodes are participating for communication, whereas other nodes are in sleep mode. So, it conserves energy. Due to the various time slots, number of collisions at the sink also has been reduced. Circular topology of this routing algorithm has number of Tiers (Tier1, Tier2, . . ……..). The node which is on the diagonal, follow its original path for communication. Each of these nodes has two possible paths for routing. Depending on the energy level of the path, it selects the path and forwards the packets. It is energy efficient, more packets received at sink.

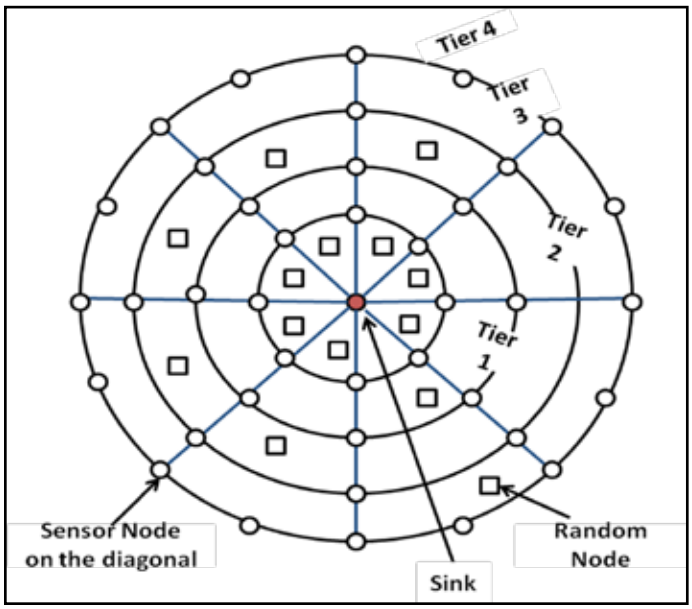

Fig. 2.6: Circular Topology

G. Grid Topology

The sensor network field dividing into grids as shown in Fig 2.7. The network area is partitioned into non-overlapping square grid with same size. There should be at least one and only one node in working state in each grid at any time.
In order to extend the network life time, the nodes in a grid should work in turn. Inside each grid, one node is selected as a grid head which is responsible for forwarding routing information and transmitting data packets. Routing is performed in a grid-by- grid manner. Grid-based multi-path routing protocol intended to route packets fast, utilize and extend sensor nodes energy in addition to avoiding and handling network congestion when happens in the network.
Wei et al.[19] organize the nodes within the grid by clustering way. The clustering head is dynamic selection according to

energy dissipation of the cluster nodes, then communicates with BS through a relaying node. This algorithm is useful to reduce node energy consumption and prolonged life of the system also enhanced the load balance of the network.

Banimelhem et al.[20] proposed congestion control mechanism in order to relieve the congested areas. This algorithm extend the network lifetime and to utilize the available storage and energy efficient of the network.

Zhibin et al.[21] proposed a joint priority-based algorithm that eliminates congestion and achieves weighted fairness in multipath and multi-hop wireless sensor network. In this paper enhance the lifetime of the network and energy efficient.

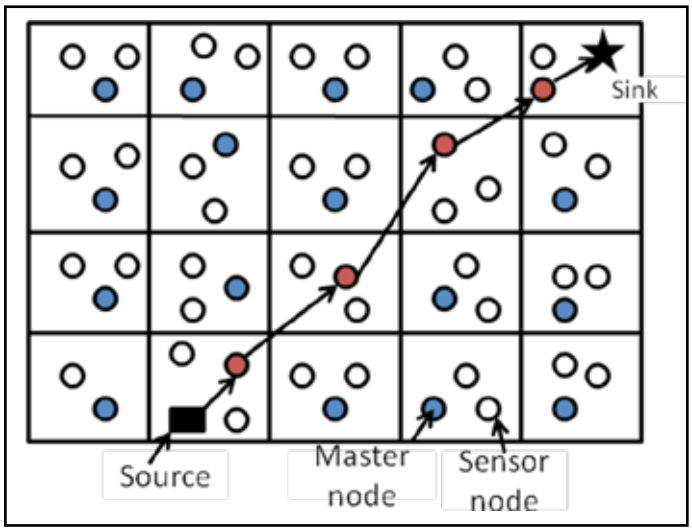

Fig. 2.7: Grid Topology

The objective of this is to route the packets before missing their deadlines with minimum energy consumption. In this section, we discuss related work that handles multi-path routing and congestion control issues in WSNs. From literature survey observed that in the previous section various routing techniques and topologies have been proposed to overcome the problem of delay, congestion in Wireless Sensor Networks. Every technique has its own advantages and disadvantages depending upon the applications. Sensors can be placed anywhere in home, environment etc. to collect the information as sensors have limited battery that is why energy consumption is more important in WSNs.

III. Comparison

The comparison in between the topologies of Wireless Sensor Network:

Performance	Bus	Tree	Star	Ring	Mesh	Circular	Grid
Path	Single	Single	Single	Double(but in same direction)	Multiple (Irregular)	Multiple	Multiple
Node Failure	More	More	More	More	Less	Less	Least
Load balance	Less	More than Bus	Less than Tree	Less	More	More	Most
Congestion in path of packets	More	More	More	More	Less	Less	Least
Packet reception ratio	Less	Less	Less	Less	More	More	Most
Energy Consumption	More	More	More	More	Less	Less	Least
Network life time	Less	Less	Less	Less	More	More	Most
Reliability	Less	Less	Less	Less	More	More	Most

In above table, comparing the performance of the topologies in terms of path, node failure, load balance, congestion in path of packets, packet reception, energy consumption, network life time, reliability.

IV. Conclusion

There are different topologies discussed above and comparison of the performance under different topologies has been done. There is a need to reduce energy consumption so as to enhance the performance of the network in terms of lifetime, congestion should be less at the sensor nodes that should be balancing the load of the network. More number of packets are received at the sink in mesh and circular topology and the most at grid. Grid topology has been found energy efficient in theoretical comparison. Future work will focus on the detailed study of different topologies in their specific applications.

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