IJETST- Vol.||03||Issue||05||Pages 3823-3830||May||ISSN 2348-9480 2016

Open access Journal International Journal of Emerging Trends in Science and Technology

Impact Factor: 2.838 DOI: http://dx.doi.org/10.18535/ijetst/v3i05.01

A Comprehensive Study on Wireless Sensor Network

Authors

Akash Nag[1], Kaushik Roy[2]

[1,2]Department of Computer Applications, SITE School

VIT University, Vellore, India

ABSTRACT

This paper depicts the idea of sensor networks which has been made reasonable by the meeting of micro-electro-mechanical systems, wireless communications and digital electronics. To begin with, the detecting errands and the potential sensor networks applications are investigated, and a survey of variables impacting the outline of sensor networks is given. At that point, the correspondence design for sensor networks is laid out, and the calculations and conventions created for every layer in the writing are investigated. Open exploration issues for the acknowledgment of sensor networks are additionally talked about.

Keywords- *Ad hoc networks, Data Link Layer, MAC Layer, Network Layer, Power aware protocols, Routing Protocols, Wireless sensor networks.*

1. INTRODUCTION

Recently there has been much advancement in the field of wireless communication and electronics which have resulted in development of cheaper, low power, multifunctional sensor nodes that are handy and can communicate efficiently in short distances.

Among variety of features of sensor networks is the co-operation of nodes. The nodes are provided with a onboard processor. In spite of sending unrefined data to the neighboring nodes, they perform calculations due to their processing abilities and transmit only relevant data.

The applications of wireless sensor networks can be seen in the areas like health, military, and home. Specifically in military, its application can be command control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems. The rapid deployment, self-organization and fault tolerance nature of sensor networks will make the applications possible. In health sector, its applications can be monitoring patients and assist disabled person. In commercial applications can be: managing inventory, monitoring products quality, monitoring disaster areas.

Though a number of protocols have designed for traditional wireless ad hoc networks, they are not suitable to be implemented in wireless sensor networks due to their unique features. Below are few differences between sensor and ad hoc networks:

- The frequency of nodes in sensor networks can be very high compared to an ad hoc networks.
- Sensor nodes are deployed densely.
- They can fail many a times.
- There is a lot of topology variations in sensor networks.
- Sensor nodes prefer broadcast
- Communication in compared to point-to-point communication of ad hoc networks.
- They have limited resources in terms of power, computational capabilities and memory.

They may not possess global identification (ID) due to large overheads and number of sensors

2. LITERATURE REVIEW

So, here we have a look at various surveys made by various authors and a detailed description of their contribution towards the study of sensor networks. During those research they had concentrated on different factors. Some concentrated their studies on network layers, like- MAC Layer, Data Link Layer, Network Layer; some other concentrated on network protocols, energy factors etc. As we all know that energy conservation is one of the most important factor for wireless sensor network. At the same time as the network works with from hundreds to thousands of sensors, energy conservation is not an easy task without affecting the network's working efficiency. Here we have discussed all the possible parameters to design an efficient wireless sensor network.

2.1. General Survey

I.F. Akyildiz, Weilian Su, Sanakarasubramaniam and E. Cayirici described a sensor network can be considered to be consisting of a large number of nodes densely situated closely to subject (physical or environmental) to be monitored. The purpose of each node is to collect information and send it to sink (base station). The positions of the nodes are not fixed, hence it becomes important that the network has self-organizing capabilities. [1]

There are some major differences between an ad-hoc and sensor networks. The various factors determining the architecture of this network can be as follows:

1) Fault Tolerance: the nodes are prone to physical phenomenon (pressure, temperature etc). hence
2) Scalability: the sensor network is all about densely presence of nodes. So the protocols need to scale such high density of the network.
3) Production Cost: a sensor network consist of a large number of nodes. So the cost of individual nodes should be cheap. Less than 1$ is preferable.
4) Hardware constraints: a sensor node consists of various electronic subunits (sensing, processing, communication, power, location finding system, power scavenging and mobilize). Even constituting these many units, it should consume less amount of power and should be very handy.
5) Sensor network topology: the topology should support high node density.
6) Transmission media: the communication will be wireless in nature, so the medium used will be RF, Infrared and Optical.

The various layers of protocol stack presented by authors are: Physical, Data Link, Network, Transport and Application. However the focus of this survey will be on Physical, Data Link and Network.

2.1.1. Physical Layer

The focus of this layer will be regarding various hardware constraints i.e. to developing modulation schemes that are power saving, solving signal propagation effects and restricting small size of the node.

2.1.2. Data Link Layer

This layer is responsible for creating a network infrastructure (self-organizing ability) and efficiently sharing communication resources among nodes.

The protocols used in this layer are as follows:

SMACS and EAR: In this model, the sensor nodes are static in nature and a higher energy mobile nodes exists. The network startup and link layer organization is achieved by SMACS by combining neighborhood discovery and channel assignments phases so that a connected network is formed by the time all nodes hear their neighbors. There is no need of global or local nodes here.

Fixed allocation of duplex time slots at fixed frequency are used. Compared to sensor data rate large available bandwidth are exploited. Seamless connection of the mobile nodes is enables by EAR, and it is also transparent to SMACS.

CSMA- Based Medium Access: Highly correlated and dominantly periodic traffic must be supported by the MAC protocol. The traditional CSMA based schemes don't support this and assumes stochastically distributed traffic mainly for point-to-point flows. Constant listening periods for energy efficiency used by this scheme and it also introduces random delays for robustness. An adaptive rate control scheme is used to achieve fairness.

Hybrid TDMA/FDMA CSMA-Based Medium Access: the hybrid TDMA-FDMA is considered to be more efficient than TDMA or FDMA. The primary concern is given to physical layer and hardware issues, without which energy efficient protocols cannot be designed. All the protocols throughout the protocol stack should be aware of the physical layer and hardware.

Small Minimum Energy Communication Network: the sensors networks which have the minimum energy path, their subgraph is created.

Flooding: data is broadcast to all neighboring nodes. It is a very simple routing protocol with deficiencies like implosion, overlap, and resource blindness.

Gossiping: data is sent randomly to one selected neighbor. Implosion is avoided but message propagation can take longer times.

SPIN: a node having available data broadcasts a description of data and is sent only nodes which express interest.

SAR: multiple trees are created where the root is 1 hop neighbor to the sink. A tree is selected by a node to be routed back to the sink on the basis of energy resources and additive QoS metric.

LEACH: a 2-level cluster hierarchy, cluster members send data to the cluster head and cluster head sends it to the base station. The dissolving of clusters at regular interval and randomly choosing cluster heads evenly spreads the energy dissipation.

Directed Diffusion: an interest is send out by the sink that propagates in the network and sets up gradient so that data can flow from sink to source.

Intanagonwiwat, R. Govindan and D. Esterin, described the problem of a wireless sensor network as-just because sensor networks have different requirements than other wireless networks, localized algorithms are designed for its robustness and scalability. Here the sensors only communicate with other sensors in close by areas. [2] They consider directed diffusion as set of abstraction that describe communication pattern underlying such algorithms. It is different from the designs features of traditional wireless networks and are data-centric and application specific in nature.

Data centric means that in we will be focusing in gaining information which matches certain specific node. Thus data from the sensor will be decoupled and node identification will not be that important. Application specific means the knowledge across all the layers of an application data aggregation, caching and informed forwarding can be performed by intermediate nodes.

A two-level cluster formation algorithm has been described, where available energy is the factor electing cluster heads. To demonstrate the difficulties that rise, a localized algorithm for object tracking has been presented. The need to produce a certain global behavior with at best indirect global knowledge makes the design of the localized algorithms difficult. In addition to that these algorithms are sensitive in choice of their parameter values.

So to overcome these problems, the design and prototyping of adaptive fidelity algorithms are suggested. Here the copy of retrieved data can be traded against network lifetime and network bandwidth. Furthermore, if we can develop techniques for characterizing of localized algorithms then quantifying the tradeoffs and production of expected behavior can be possible.

To model the communication patterns of localized algorithms, it is proposed to use “directed diffusion” as an abstraction to frame the communication patterns. Data generated by each sensor can be characterized by certain attributes. If other sensors are interested in certain type of data, they can spread out this interest to the network. According to the interest, gradients are established channelize the diffusion of data when it is available, i.e., for data that matches an interest, a reverse path is established.

2.2. Routing Protocols

According to D. Braginsky and D. Estrin -it is important to deliver queries to the nodes which have observed certain events in a network and to get back to the point where the interest was expressed. Establishing a global co-ordinate system and performance geographic routing are some ways to achieve this. Another simple approach can be to flood the query or event. But these schemes are being inefficient when it has to deal with a steep number of nodes that has to operate under severe power constraints, and network’s data centric nature. Routing of queries is done based on the event observed and not based on unique id or the location of the node. This makes is possible to retrieve data from the network on the basis of event and not any network addressing schemes or geography. [3]

Query and event flooding are the solutions to the problem. In case of query flooding, the network gets flooded with query and here the number of transmission does not depend on number of events. The scheme can be used where the number of events is greater than number of queries. In event flooding, on witnessing an event the network is flooded and other node can setup gradients to it, through queries can be routed. Here too the number of transmissions is independent of number of queries and is helpful when number of events is less than the number of queries.

A logical compromise exits between query and event flooding and that is Rumor Routing. In this, the paths are created (may be multiple or non-optional) which takes each event. The query is sent to a random walk until it crosses one of these paths and this leads to the event of interest. Sometime the queries will not cross will not cross any paths, in that case query flooding can be used as a final option.

A set of long-lived agents (packets moving between nodes) are used in the algorithms which creates path towards the event that has been encountered. An agent is generated probabilistic-cally whenever some event is witnessed and the agent travels through the network initializing node’s event forwarding table. As the agent travels, with visit of each table node it synchronizes its own event table. Due to this, the path information is propagated and it learns about new events and can propagate them further.

A straightening algorithm is employed to determine the next hop and avoid loops. The agent leaves a thick path as it travels due to the broadcast nature of nodes, so that nodes close to the agent’s path can update their own event tables. Although it is possible for any node to generate an agent, however it is good to be generated by a node that has observed events, so that useful information can be spread immediately.

The query to the next hop is routed if the node has an entry for the event in its event table whenever a query is generated. In other case, it chooses to a next hop guessing that it will cross the path to the event. It is better to forward queries along a straight path. There are possibilities that the query will reach its TTL before crossing a path towards the event, and in this case can perform query flooding.

According to the simulation test bed which included randomly scattered nodes over an area of 200X200 m^2, 1000 queries were generated after scattering events over an area and letting the agents setup their paths and also the number of successful routed queries recorded. The results for most parameters tells that Rumor Routing achieved important saving over flooding till a certain event cost threshold without the sacrifice of delivery rate. It handled node failure nicely by degrading its delivery rate in a linear manner with number of failed nodes.

The authors, W.R. Heinzelman, A. Chandrakasan and H. Balakrishnana, bring us here a 2-level hierarchical routing protocol (LEACH) which tries to makes less energy dissipation and distribute energy consumptions equally across various nodes. This happens because of the clusters being formed with local coordination, by rotating high energy cluster heads and compressing local data. [4]

Here are some assumptions made regarding the model:

- There is only one base station that is fixed where there are no energy constraints and the sensor nodes in large number are stationary, homogenous and energy constrained.
- The communication between base station and the sensor nodes are considered to be expensive.
- The job of the network is to gather information at fixed rate through sensing and transmit it to the base station. There is a lot of raw data due to this and divided locally into small set of information that can be understandable.

The nodes self-organize into local clusters such that one node in each cluster acts as the head of the cluster. After the cluster is formed, the nodes send the data to the cluster head and the cluster head sends it to the base station. This is called 2-level hierarchy.

This operation is divided into rounds during which the cluster are dissolved and recreated. At each round one of the nodes decides whether it should be cluster head or not. The decision is made based on the number of the percentage of cluster heads and the number of times a particular node has been made a cluster head. The cluster head spread their intention through advertisements and the nodes decide which cluster they have to join on the basis of signal strength. After the cluster head is made it creates a TDMA schedule and sends it to cluster members. To avoid interference, each cluster uses different CDMA nodes.

A comparison was made between a direct communication protocol and minimum energy routing protocol. The following conclusion were made about the latter:

- It doesn’t take into account the possibility that the nodes can failed subject to unfavouring environments.
- The cluster head are not distributed uniformly. As cluster heads are made on basis of some probability, there are chances that some cluster will be left without any cluster head.
- In the comparison only 100 nodes were considered, which is very less compared to direct communication protocol.

2.3. MAC Layer

A Media access control should be energy efficient and should allow allocate fair bandwidth to every nodes. Here CSMA based MAC has been considered for sensor networks. A. Woo and D.Culler described the strategy of CSMA is to listen to the channel before transmission based on positive and negative acknowledgements to represent collision. They rely on timely synchronized channels or to perform collision detection. Though these features are not directly applicable on sensor networks due carried features of this network.[5]

- It works in collective structure.
- At times, traffic can be very high.

- Every node acts as a data source and a router.
- The capabilities of nodes are restricted.
- There should be equal cost per unit when it comes to listening, receiving or transmitting.

The media access control is categorized into smaller mechanisms named listening, backoff, contention control and rate control. Listening and backoff: the nodes will sense an event and try to transmit it at same time. Here it has been proposed that whenever the nodes need to transmit they introduce random delay with constant listening period. If the channel is free, then transmission is possible or else they enter backoff phase in which the radio is switched off. This backoff phase is also applied as a phase shift to desynchronize the nodes.

Contention control: It uses a minimum number of control packets. If the traffic allows then a combination of request-to-send(RTS) and clear-to-send(CTS) control packets can be sent.

Rate control: MAC should manage the originating rate of data of a node to allow route through traffic to access the channel and reach the base station. The proposed adaptive rate control rate identifies loss as collision and adjusts transmission rate similar to congestion control in TCP.

For all the results the CSMA schemes are checked over a single hop which consist of 10 nodes with a base station in the middle. The parameters considered here are: delay before listening, listening period, and backoff mechanism used.

- The schemes show good channel utilization and are insensitive towards the presence of backoff. However backoff is of great importance to maintain the proportional fairness when a fixed window size is used or exponentially decreasing window size.
- Robustness is achieved thorough randomness in pre-collision phase.
- The schemes having constant listening period attain best energy efficiency.

For nest scenario a 5 level deep multihop environment was considered. Here the CSMA are augmented with a transmission control protocol so that the nodes can adapt the data origination rate to give a fair share to downstream nodes and match available upstream.

- CSMA which have no contention or rate control mechanism failed to deliver the packets more than two level down. This happens because of hidden node problem and also of the fact that the collective behavior of nodes are not considered.
- During the use of RTS/CTS contention scheme, nodes that are deep in network can deliver packets to the base station but a fair bandwidth allocation is not attained. Nodes that are close to the base station consume whole of the channel for their own traffic and very less is left for other nodes.
- When a rate control mechanism was used the fair allocation of bandwidth among originating and route-thru traffic was achieved.
- The adaptive rate control proves efficient in balancing the in node generated traffic with the route thru traffic by using traffic packet loss as a signal to decrease traffic.

2.4. Energy

A.Ephremides worked on the most important factor-Energy. In his model the major energy efficiency issues in ad-hoc networks are focused which are considered to be infrastructure less and also require multiple hops to to connect to each other. Vertical layer integration and criticality of energy consumptions are two main characteristics that constitute the design of ad hoc networks. [6]

Transmitting, receiving, and listening are the three major operation of any wireless node. A node in listening mode consumes less energy. However, if it spends a lot of time listening, the consumption of energy gradually increases.

In multi-hop scenario it is better to choose long paths along short hops and not the opposite. Communication performance is as important as energy consumption. However choosing of many sort hops doesn't solve the problem as the delay increases and processing energy also increases which further increases the control overhead.

There is a distinction between whether energy is to be treated as a cost function or as a hard constraint. In the first case, the aim of the designer is to minimize energy per communication task, and to treat energy as an never ending resource. But if energy is hard constraint, it should be considered limited. Here the designer's job is to choose between: maximizing the longevity of the network or communication performance.

2.5. Security

In wireless network security is another important factor to take care about.The main challenge is to provide secure association between master or slaves or between nodes in an ad hoc network. [7][8]

The proposed solution is Resurrecting Duckling security model. Here the slave is the duckling and the master is the mother duck. This inspires from real world that a young duckling after coming out from the egg recognizes the first moving object making sound as its mother. This is called imprinting. At a time, a device can be either in one state (a) imprintable or (b) imprinted.

The imprinting takes place using physical electronic contact, during which a secret key is transferred which connects the device to a specific master forever. The device will follow only a specific master unless compelled to become impritable again.

The model was considered limiting as it didn't allowed interaction with other devices. Its extension was to include specification of policy where for every action the master device specifies what credentials to be presented by another device in order to request that action.

Another problem in wireless sensor network is to avail secure communication and authentication in wireless ad-hoc networks not considering public key infrastructure. This challenge discussed by D.Balfanz, D.Smetters,P.Strewart and H.Wong [9] in their research work as follows:

The approach is an extension of "resurrecting duckling policy model" which gives bootstrap secure wireless communication by pre-authentication over a location limited channel. There is a difference between location limited channel and main wireless link and the former is chosen as it avails two properties: (1) demonstrative identification; (2) authenticity.

This approach doesn't consider secrecy as in "Resurrecting duckling policy" which makes it unaffected to eavesdropping. This is done through public key cryptography. The location-limited channel used by the participants to exchange the public keys. This ignores the pre-authentication phase and the participants can proceed to authenticate themselves over the channel and establish a secret key for their session.

3. CONCLUSION

The number of surveys and the various parameters on which wireless sensor networks open to us a new technology which possess the change the face wireless communication in future. With features like flexibility, fault tolerance, high sensing fidelity, low cost, and rapid deployment, it creates application areas for remote sensing. Its wide range of application can make it an integral part of everyone's lives. Although it faces various problems like scalability, hardware, topology changes, power consumptions etc. A number of studies are being done so that wireless sensors satisfy the above criteria and it becomes possible so that wireless sensor networks are applicable in daily lives of people.

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