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GEOGRAPHICAL AND SIGNALING BASED ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS

The main goal in wireless sensor nodes (WSNs) is to minimize energy consumption, computation and communication between nodes. So far many routing algorithms were proposed for wireless sensor networks. Early developed algorithms were mainly related to topology-based routing schema, where next hop was determined according to current stage of router. In wired network topologies all routing information can be obtained as all nodes in the network are interconnected. But in wireless networks the same principle does not work well. That is why for wireless sensor network different kind of routing protocol is required. In this paper we didn't consider acknowledgement of delivery of packets in transport layer. We proposed routing protocol schema that affects the energy consumption and computations in the limited source hardware.

Key words: *wireless sensor networks, routing protocol, protocol stacks, network management.*

Introduction

Implementation of the state of the art protocols and network management designed for traditional wireless network faces with some difficulties in wireless sensor networks (WSNs), because of their unique characteristics. The main goal in conventional wireless networks is mainly focused on the quality of services, optimization of response time, finding the best way without data loss and etc. But in WSNs the primary goal is to minimize energy consumption, computation and communication between nodes [1]. Because of hardware constraints, transmission of radio signal covers only short distance from the node, which in turn leads to additional functionalities of sensor nodes, i.e. devices act as routers and end systems at the same time as given in figure 1. Therefore they are prone to communication failure [2]. Designing of network protocol for monitoring and controlling communication among sensor nodes and mainly controlling of battery usage are the important issues in wireless sensor networks architecture. Besides network protocols a network management system is also important concept in WSNs.

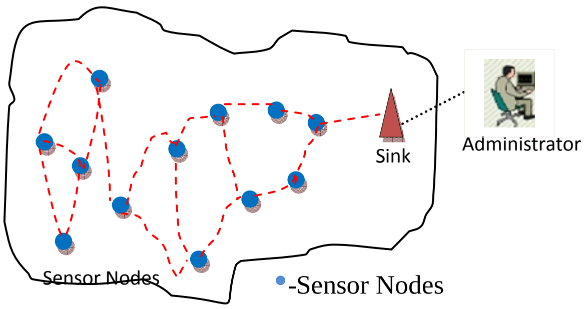

Figure 1. Typical Wireless Sensor Networks.

A network management system designed for WSNs should provide a set of management functions that integrate configuration, operation, administration, security and maintenance of all elements and services of a sensor network. We focus on protocol design in the network and physical layer that provide connectivity among sensor nodes. System management is beyond the scope of the paper.

The main task of WSNs is to observe and sense phenomenon in the specific areas, to gather required data periodically or automatically and to transmit them to the destination node called the sink and after that the sink transfers them to the administrator. Specifically, sensor nodes should involve optimized network management tools in order to perform variety of management control tasks based on the data received from other nodes [3, 4]. An example for management control tasks might be shown a sampling frequency, switching node on and off, wireless bandwidth usage, traffic management, fault management and others. It is essential to find the shortest path from source node to the sink that consumes less energy.

Network topology is also one of the factors that affect network protocol design. Sensor nodes are typically deployed in remote or harsh conditions and the configuration of them are changed dynamically. Therefore network protocol should allow the network to self-forming, self-organise, and ideally to self-configure in the event of failures without prior knowledge of the network topology [2]. However, most sensor network applications are designed with network protocol in mind and thus no extra network layer is required.

So far many routing algorithms were proposed for wireless sensor networks. Early developed algorithms were mainly related to topology-based routing schema, where next hop were determined according to current stage of router [5, 6]. In wired network topologies all routing information can be obtained as all nodes in the network are interconnected. But in wireless networks the same principle does not work well. That is why for wireless sensor network different kind of routing protocol is required [7].

Location based routing schema has been investigated by many researchers [8]. Several novels geographic (also termed position-based) routing algorithms have been proposed, which allow routers to communicate each other based on location coordinates [9–11]. Information of physical location might be determined by means of a global positioning technique like GPS, or relative positioning based on distance estimation on incoming signal strengths [12, 13]. Geographic routing requires that location information of both of the nodes (source node that gathered data, and destination node called sink that receives gathered data) should be encapsulated in frames.

Moreover, location information of the sink should be announced in advance. In this research, we propose new location (geographical) based network protocol design that will address Network and MAC layers separately. For simplicity we focused on signaling and GPS location based routing protocol with acknowledgement and proposed algorithm for delivering data over the sensor nodes from source node to the sink. In this paper we didn’t cover result analysis of the model. In section 1 we covered general information about wireless sensor networks, in particular, protocol stack and Spherical Coordinates with the GPS. In section 2 we showed the proposed methodology. Finally in section 4 give conclusion part of the paper.

Overview of WSNs

Wireless sensor networks are composed of a large number of small-sized devices scattered through the area to be observed. They observe the phenomenon in the area, gather data and send them to the station called the sink. The sink is an intermediary between system administrator and sensor nodes. A connection type between the sink and the administrator might be a regular wired line (i.e, internet) or any Ad-Hoc technology based on the IP connection. Sensor network applications use a data-centric approach that views a network as a distributed system consisting of many autonomously cooperating sensor nodes [14], any of which may have a role in routing, data gathering, or data processing. Each node also plays role of router, so that they forward any receiving data, unless this doesn’t belong to one of them.

Gathering data can be also handled by the sink. In general there are several ways of gathering data; it might be either periodically, on sensing time or event-driven.

The data gathering application requires sensor nodes to periodically report their data to the base station. In the event-driven application, nodes only send data when an event of interest occurs.

Management Functionality

The function of network management systems is to monitor and control a network. These activities are wide ranging, and in this section we classify existing sensor network management systems in terms of the functionality they provide. Systems for sensor networks that are based on traditional network management systems include BOSS [15] and MANNA [16]. BOSS serves as a mediator between UpnP networks and sensor nodes. MANNA provides a general framework for policy-based management of sensor networks. sNMP [17] provides network topology extraction algorithms for retrieving network state. Other researchers have designed novel routing Protocols for network management. For example, TopDisc [18] and STREAM [19] are used in sNMP for extracting network topology, RRP [20] uses a zone flooding protocol, SNMS [21] introduces the Drip protocol, and WinMS [22] is based on the FlexiMAC protocol. Fault detection is an important focus of the systems TP [23], Sympathy [24], MANNA [25], and WinMS [22]. TinyDB is a query-based interface that allows the end user to retrieve information from sensor nodes in a network. MOTE-VIEW also allows the end user to control sensor node settings such as transmission power, radio frequency, and sampling frequency.

In these systems the central server analyses data collected from the network. The main disadvantage of such passive monitoring schemes is that they are not adaptive to current network conditions, and provides no self-configuration in the event of faults. The end user must manually manage the network and interpret the graphical representation of collected data.

According to [26] management functionality consists of *power management, mobility management, task management*. Power management controls trade-off between energy consumption and computational task. Therefore well designed and energy-aware network protocols are required that demanded less computation by using limited sources, for example, controlling of retransmission of data packets, turning on/off of nodes. Routing protocol is more efficient part that makes intermediary nodes turn on and off. Therefore it should be well designed in order to minimize the activation of nodes and transmission period. Mobility management is due to the use of location aware methods, recognizes the removal of the node and records it. Thus the trail of the moving node will be followed and it will be managed if needed. Task management is to control task order in the node queue. It might involve either normal data queue or task management queue. But this task can be put on some of the nodes which are more reliable or have fewer tasks to do or have more energy. However, the nodes in a sensor network can work together with energy aware methods and route the data in a moving sensor network and commonly use the sources among the nodes. General management functionality is shown in figure 2 [26].

Protocol Stack

As we mentioned above main function of the sensor node is to collect observed data and forward them to the sink and vice verse. Here the sink can route gathered data through the internet to the administrator. The protocol stack used by the sink and all sensor nodes is given in figure 2 [26].

The protocol stack consists of the application layer, transport layer, network layer, data link layer, physical layer. In application layer different types of software are deployed related to functionality of the sensor. The transport layer controls data flow from the application layer to lower layers. It controls number of segments of whole data and re-

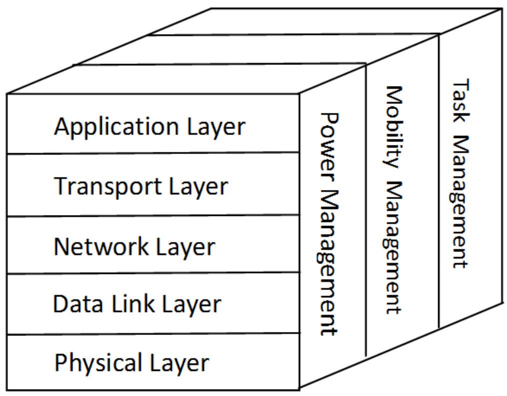

Figure 2. The sensor network protocol stack and management functionality.

combination of arriving packets. The network layer takes care of routing the data supplied by the transport layer. Since the environment is noisy and sensor nodes can be mobile, the MAC protocol must be power aware and able to minimize collision with neighbors' broadcast. Creating frames, packet modulation, transmission and receiving techniques are take place in the physical layer addresses. In this research we are interested in the network and Physical Layer.

Proposed Method
GPS based distance coordination

In this section we develop simplified formulas for finding the distance between two points on the earth. The coordinates of each of the two points in the GPS system are given in the form AA.AAA degrees, BB.BBB minutes. This is the form used by many Global Positioning Systems. We use a simplified model of the earth. In this model the earth is a sphere whose radius is 6367 kilometers. Because the earth is not a sphere this model is somewhat inaccurate. For our purposes, in WSNs distance among nodes is measured in meters, that is why it is a good first approximation. The first step is to convert the measurements of latitude and longitude into a more usable form. Since there are 60 minutes in a degree, the number of degrees is given by

$$DEGREES = AAAAA + BB.BBB / 60$$

We use spherical coordinates in this paper. The figure below compares spherical coordinates (in degrees) with latitude coordinates. In spherical coordinates we measure the angle α from the North Pole. Thus, the North Pole corresponds to α=0; the equator to α =90 degrees; and the South Pole to α =180 degrees (figure 3).

Thus, the following formula converts from latitude expressed in degrees to α expressed in radian.

$$\alpha = \begin{cases} (90 - latitude)\dfrac{\pi}{180}, & if\ latitue\ is\ North \\ (90 + latitute)\dfrac{\pi}{180}, & if\ latitue\ is\ South \end{cases}$$

In spherical coordinates we measure the angle θ (in radian) starting at the prime meridian (longitude 0) and moving east. Thus

$$\theta = \begin{cases} longitude \times \dfrac{\pi}{180}, & if\ longitude\ is\ East \\ -longitude \times \dfrac{\pi}{180}, & if\ longitude\ is\ West \end{cases}$$

Next we want to express the location of a point in Cartesian coordinates with the origin at the center of the earth, the North Pole at the point *North Pole = (0, 0, 6367 kilometers)* and the positive *x*-axis going through the prime meridian. The conversion formulas are:

$$x = 6367 (\cos \theta) (\sin \alpha)$$
$$y = 6367 (\sin \theta) (\sin \alpha)$$
$$z = 6367 (\cos \alpha)$$

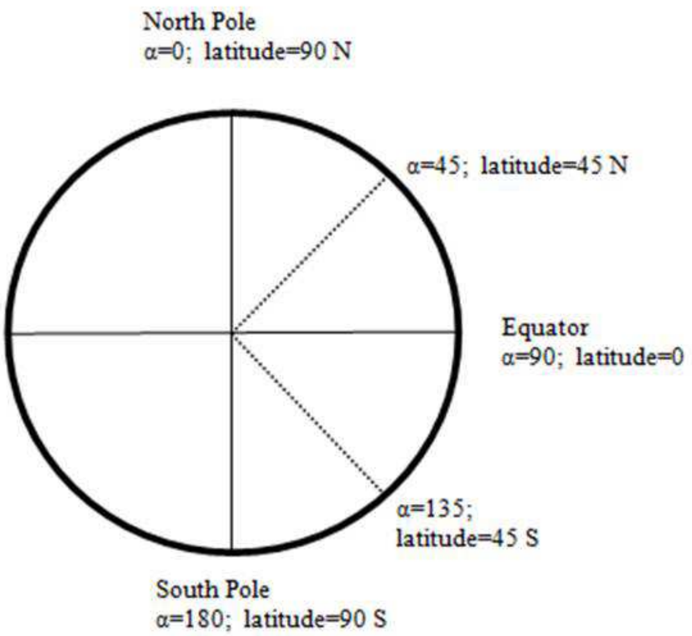

Figure 3 Values of the angle α from the North Pole and latitude on the Earth

Using these formulas we can determine the Cartesian coordinates of any point from its latitude and longitude. For example, the Cartesian coordinates of two points given in GPS system, say

$$A = \begin{cases} 35\ degrees\ 17.299\ minutes\ North\ and \\ \quad 120\ degrees\ 39.174\ minutes\ West \end{cases}$$

and

$$B = \begin{cases} 46\ degrees\ 36.003\ minutes\ North \\ 112\ degrees\ 02.330\ minutes\ West \end{cases}$$'

are as below:

	A	B
x =	-2650	-1641
y =	-4471	-4055
z =	3678	4626

The distance between these two points is 1,446 kilometers, but this distance is the straight line distance through the earth.

Signaling Based Routing Protocol Methodology

As we mentioned above a sensor networks technology have wide range of application areas, where they have specific properties and factors affecting designing of network topology such as location of usage, unattainablity, and etc. The proposed model is based on geographical location in order to determine a routing path from source node to a sink. For that purpose all sensor nodes in an observation area need to be embedded GPS equipment on it. In general, energy consumption of GPS hardware is too low and therefore effect of it to energy stability of whole system is measured as 0.5%-1% within the period of 2 – 3 years from deployment [27] In the model proposed, time for activation of GPS equipment, searching for a location update, gathering location coordinates and storing data in the specific file can be manually set up by administrators. In stationary system an ideal period of update is once a week that will lead to very less energy consumption.

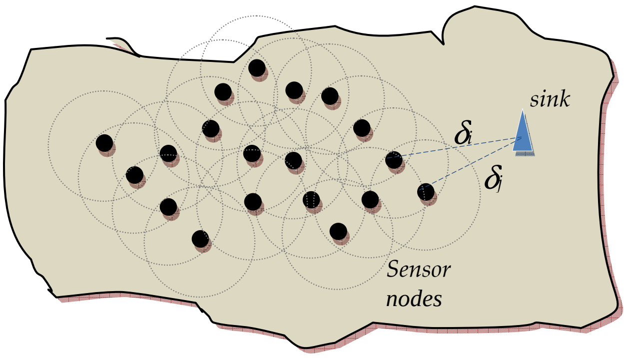

Figure 3. General view of the model

Table 1. List of variable used in the algorithm.

Variable	Defination
δ_i	Distance between the node transmitting packets and the sink. Here distance is measured based on Spherical Coordinates and the GPS coordinates calculation, and refers to direct link between them as shown in figure 2.3
r_{GPS}	GPS coordinates of the sink
$\Delta\delta_i$	Distance error in each node. Sometimes GPS coordinates is not accurate and in order to compensate error in comparison of distances of each node to the sink this variables are used. This value can be manually set up in each node by administrator or can be set up with some default value.
b_i	It controls whether the next hop is the sink. If b_i is equal to *1* then the next node is the sink, otherwise it is an intermediary node
r_i	Radius of coverage area of each sensor node.

In this model we proposed a signaling based routing protocol, where signaling among neighbor nodes are need in order to find the closest node to the sink. After that gathered or arrived data is transmitted to the specified node. For that reason, source node send signaling packet that includes GPS coordination of the sink, and its destination to the sink. Here the GPS coordinates of the sink should be manually stored into the nodes that sense a phenomenon. As intermediary nodes accept the frames where the GPS coordinates of the sink are given, to record them in the intermediary nodes is not necessarily. The source node that observes phenomenon gathers data. After segmentation process in transport layer, packets are created in network layer followed by the procedure of encapsulation of packets into frame. Before sending packet, source node sends signal that includes GPS coordinates of the sink r_{GPS} (definition of variables are given in Table 1), which manually installed to each node by administrator, distance between the node transmitting packets and the sink δ_i, and b_i, that shows whether the next hop is the sink. If b_i is equal to *1* then the next node is the sink, otherwise it is an intermediary node. δ_i and r_{GPS} are unique parameters to find out sender nodes transferring packets. The source node give zero to b_i as an initial value and then broadcasts it to its neighbors. When each intermediary sensor nodes receives packets they control whether it belongs to them or not by using r_{GPS} parameters. If it belongs then the destination node-the sink put value one and transfer it back to the sender node. When sensor nodes accept the signal, they calculate their distance till the destination node-the sink, and send this value including b_i parameter back to the destination node. When the sender node accepts the signal from neighbor nodes it calculates the next nearest node to the sink with the following method. The node finds the *min* δ_i by using Spherical Coordinates that satisfies $\delta_i > \delta_j + \Delta\delta_i$ (δ_i is for a node transferring packets and δ_j, *is* for a node receiving packets), then the node encapsulates frame including GPS coordinates of j^{th} node and transfers the packet the j^{th} node. When nodes, in the vicinity of the sender nodes, accept the packet, they will control the GPS coordinates in order to determine whether the packets belong to them or not. This mechanism will go on till the packets reach to the sink. Figure 4 gives general view of the model. Furthermore, it should be considered in network design that some of the intermediary nodes must be in the coverage area of other sensor nodes in order to create a communication chain from the source node to the sink. The proposed model with the unique characteristics of simple signaling method facilitates of calculation and transferring of packet. Since we don’t consider acknowledgement in transport layer, signaling process before sending packet is required which in its turn makes communication easier.

Conclusion

In this article, the overall view of sensor network's design, protocol stack, routing protocol was presented. Besides the sensor management systems reviewed in this chapter have been discussed. The systems are characterized by their power consumption, memory consumption, bandwidth consumption, fault tolerance, adaptability, and scalability, routing protocols and etc. None of the reviewed systems provides a fully integrated view of all sensor network management design factors. We touched the problem of data transmissions over WSNs in general, and the particular network design was proposed. Wireless sensor networks are composed of a great number (which may reach thousands) of small sensors and low-cost nodes with high capabilities, low energy storages and limited hardware computation. Therefore routing protocol should be designed so that energy consumption is less and existing hardware is able to carry out the computational issues. Proposed model for sensor networks has new control and observing models which find the location of next nodes by simply sending signaling messages. In this paper we didn’t consider acknowledgement of delivery of packets in transport layer. We proposed routing protocol schema that affects the energy consumption positively and decreases computation in the limited sourced hardware.

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Simsiz sensor şəbəkələrində coğrafi və siqnallaşma əsaslı yönləndirmə protokolu
Simsiz sensor şəbəkələrində əsas prioritet məsələlər enerji istifadəsinin və hesablama əməliyyatlarının azaldılmasından ibarətdir. Bu günə qədər bir çox yönləndirmə protokolları təklif olunmuşdur. Təklif olunan modellərin əksəriyyəti öncədən məlum olan topologiya sisteminə əsaslanır və bunun nəticəsində də növbəti addımı asanlıqla təyin etmək olur. Lakin simsiz sensor şəbəkələrində növbəti addımı məlum olmadığından, simli şəbəkələrdə istifadə olunan topologiyaların bu sistemlərdə tətbiqi mümkün olmur. Bunun üçün simsiz sensor şəbəkələri üçün yeni yönləndirmə protokollarının tərtib edilməsinə ehtiyac var. Bu məqalədə simsiz sensor şəbəkələri üçün yeni yönləndirmə protokolu təklif edilmişdir. Təklif olunan protokol coğrafi və siqnallaşma əsaslı olub, enerji istifadəsinin azaldılmasını təmin edir.
Açar sözlər: *simsiz sensor şəbəkələri, yönləndirmə protokolu, protokol sistemləri, simsiz şəbəkə idarəetmə sistəmləri.*

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Протокол маршрутизации в беспроводных сенсорных сетях на географической и сигнальной основе
Основной целью в WSNs является минимизация потребления энергии, вычислений и коммуникаций между узлами. На данный момент для беспроводных сенсорных сетей были предложены многие алгоритмы маршрутизации. Ранее разработанные алгоритмы были в основном связаны со схемой маршрутизации на основе топологии, где следующий ход был определен в соответствии с нынешним этапом маршрутизатора. В топологии проводных сетей вся информация маршрутизации может быть получена благодаря тому, что все узлы в сети связаны между собой. Но в беспроводных сетях тот же принцип работает не очень хорошо. Именно поэтому для беспроводных сенсорных сетей требуется протокол маршрутизации другого вида. В этой статье мы не рассматриваем подтверждение доставки пакетов на транспортном уровне. Мы предложили схему протокола маршрутизации, которая влияет на потребление энергии и вычисления в аппаратах с ограниченными ресурсами.
Ключевые слова: *беспроводные сенсорные сети, протокол маршрутизации, стеки протоколов, управление сетью.*