Wireless Sensor Networks– Selection Of Routing Protocol For Applications

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Abstract

Due to the differences between Wireless Sensor Networks (WSNs) and other wireless networks, new network architectures have been developed and many new routing protocols have been proposed for these architectures. Moreover, a wide variety of applications and systems with vastly varying requirements and characteristics have been designed and implemented. As a consequence, it is daunting for deployment engineers to select network architectures and associated routing protocols for application areas of WSNs. Since the selection of routing protocols for WSNs is closely related with the application requirements and routing protocol characteristics, there is no "one for all" architecture or routing protocol solution. To date no criteria for selecting appropriate routing protocols for a particular application area has been published. This paper presents a table that enables deployment engineers to select appropriate routing protocols that are suitable for a particular application and which will maximize the return from the deployed network.

Categories

[Wireless Sensor Networks]:WSNs design issues: [Routing Protocol]

General Terms

Routing protocols, Applications

Keywords

Wireless Sensor Networks, Routing protocols, Applications

I. INTRODUCTION

Wireless sensor networks (WSNs) have gained much attention in both industry and research communities because they are expected to bring the interaction between humans, environment, and machines to a new level. Despite being a fascinating topic with various visions of a more intelligent world, there still exist many issues to be resolved to realize WSNs. Most research projects define WSNs as networks consisting of independent, collaborating nodes that can sense, process, and exchange data as well as act upon the data content.

In the recent past, wireless sensor networks have found their way into a wide variety of applications and systems with vastly varying requirements and characteristics. At the same time, various routing protocols have been designed and developed for WSNs because the routing in WSNs is distinguished from other networks. These routing protocols may differ depending on the application and network architecture. As a consequence, it is difficult for researchers and network deployment engineers to select appropriate routing protocols for a research project or an application. In order to solve this problem, a selection table outlining appropriate WSN routing protocols for specific applications is developed in this paper.

Currently existing WSN routing protocols are reviewed and their characteristics are classified in this paper. In addition, WSN application areas like environment monitoring, habitat monitoring, health care, and home application are also reviewed; their characteristics are classified and compared in tabular form. Depending on the investigation, application specification, and routing protocol characteristics in WSNs, some characteristics of a particular routing protocol can meet a particular application's requirements. If the major characteristics of a routing protocol meet particular requirements of an application, the routing protocol is identified as an appropriate protocol for this application. As a consequence, the appropriate routing protocols for particular applications are selected and a selection table is developed.

The reminder of the paper is organized in three main parts as follows: The first part summarizes some typical application requirements based on WSN design factors. The second part reviews existing routing protocols designed for WSNs and a comparison table is presented in order to classify their characteristics. The final part selects appropriate routing protocols for applications in WSNs based on the findings of the previous two parts. Finally, a table of results and conclusions are given.

II. MOTIVATION

Akkaya *et al* explored the WSN routing protocols based on network architecture developed in recent years in their survey on routing protocols for wireless sensor networks [1]. At the same time, Romer and Mattern presented the design space of WSNs and made a survey on applications for WSNs [2]. Neither of these two reports investigated routing protocol characteristics related to specification of a particular application. There is no work in literature that presents methodology to select an appropriate WSN routing protocol for particular applications based on the routing protocol characteristics and application requirements. This paper aims to resolve this issue and provides a comprehensive way to select appropriate routing protocols for a particular application.

III. WSN DESIGN SPACE

Initial research into WSNs was mainly motivated by military applications. More recently, the civilian application domain of wireless sensor networks have been considered, such as environmental and species monitoring, production and healthcare, smart home etc. These WSNs may consist of heterogeneous and mobile sensor nodes, the network topology may be as simple as a star topology; the scale and density of a network varies depending on the application. To meet this general trend towards diversification, important dimensions of the sensor network design space were discussed and characterized by Romer and Mattern [2].

Node deployment, Mobility, Node Size, Heterogeneity, Communication Modality, Infrastructure, Coverage, Connectivity, Lifetime, Network Topology and *quality of service (QoS)* are the dimensions of WSN design space presented in Ref. [2].

Node Deployment, *Network Topology*, and *QoS* are employed and other dimensions are modified or eliminated in order to classify WSNs applications related with routing protocol design issues in this paper.

Mobility: As nodes in WSNs are assumed less mobility than wireless ad-hoc networks and most routing protocols were specifically designed for fixed nodes instead of mobile nodes, only immobile applications are discussed in this paper, but mobility is still a crucial issue in WSNs and will be discussed in the future work.

Modality: This dimension is not employed in this paper to classify applications, because all the applications mentioned in this paper are radio based or could be radio based.

Node Capability: This dimension is similar as Heterogeneity and Node Size in Ref. [2]. Depending on the actual needs of an application, sensor nodes may vary from powerful Personal Digital Assistant (PDA) to tiny energy constrained nodes. Nodes may differ in the type of attached sensors; some powerful nodes may collect, process, and route sensory data from many more limited sensing nodes. Some nodes may be equipped with special hardware such as GPS and video devices etc. The nodes capability varies depending on the cost, size, resources, and heterogeneity

Scale and density: This dimension modifies Network Size and Connectivity in Ref. [2]. With a sparse density, only parts of the area of interest are covered by the sensor nodes; with a dense one, the area of interest is completely covered by sensors; with a redundant one, multiple sensors cover the same area. The network lifetime can be extended by switching the redundant nodes to power-saving sleep modes. Scale means how many nodes are deployed. High density is a key to robust systems: many nodes can compensate when a neighboring node fails and thus keep the network working as normal. Selection may be classified as:

Data delivery model: This dimension is closely related to the routing protocol design. The data delivery model will affect selection of routing protocols. They can be partitioned into five classes: event-driven vs. query-driven vs. Location-awareness; continuous data delivery vs. periodic;

Data amount and frequency: Since some routing protocols can only achieve ideal energy saving and lifetime extension when the data amount or exchange frequency is low in the network, this factor is important for routing protocols selection.

QoS: The quality of service in this paper means the quality service required by the application, it could be the length of life time, the data reliable, energy efficiency, and location-awareness, collaborative-processing. These factors will affect the selection of routing protocols for a particular application.

IV. SURVEY OF ROUTING PROTOCOL IN WSNS

Due to WSNs differing from one network to another, many new algorithms have been proposed for the routing problem in WSNs. These routing mechanisms have considered the characteristics of sensor nodes along with the application and architecture requirements. Almost all of the routing protocols can be classified according to the network structure as flat, hierarchical or location-based. Furthermore, these protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, and coherent-based, depending on the protocol operation [3].

WSNs have several restrictions, such as limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. Many factors influence the design of routing protocols in WSNs. For example, *network deployment*; *network dynamic*; *data delivery model* and *data Aggregation* are major WSNs system design issues, as summarized in Ref. [1]. In addition, Al-Karaki et al deemed the following factors to also influence WSN routing design: *energy consumption*, *scalability* and *QoS*.

Data latency and *overhead* are also considered as the factors that influence routing design in this paper. As in-network computing, data aggregation and multi-hop relays cause Data latency, realtime data is infeasible in these algorithms. In addition, some routing protocols create excessive overheads to implement their algorithms, which are not suitable for serious energy constrained networks. Thus it can be seen that data latency and overhead are two important factors which affect WSN routing protocol design.

The aforementioned factors are used to informally characterize and classify WSN routing protocols in Table 1. As Ref. [1] and Ref. [3] have already presented surveys on existing routing protocols in WSNs, the specification of individual protocol will not be presented again in this paper. This table is based on the survey of Ref. [1] and modified according to application requirements. The original paper for each protocol is referred in Table 1

	Classification	**Power Usage**	**Data Aggregation**	**Scalability**	**Query Based**	**Latency (delay)**	**Overhead**	**Data delivery model**	**QoS**
SPIN [13][14]	Flat	Ltd.	Yes	Ltd.	Yes	Mod.	Low	Event driven	No
Directed Diffusion [15]	Flat	Ltd.	Yes	Ltd.	Yes	Mod.	Low	Demand driven	No
Rumor Routing [16]	Flat	N/A	Yes	Good	Yes	Mod	Low	Demand Driven	No
GBR [17]	Flat	N/A	Yes	Ltd.	Yes	Low	Low	Gradient	No
CADR[18]	Flat	Ltd.	No	Ltd.	Yes	Low	Low	Continuously	No
COUGAR [19]	Flat	Ltd.	Yes	Ltd.	Yes	Mod	High	Leader, query	No
ACQUIRE [20]	Flat	N/A	Yes	Ltd.	Yes	Mod.	Low	Complex query	No
LEACH[21]	Hierarchical	High	Yes	Good	No	Low	High	Cluster-head	No
TEEN & APTEEN[4] [22]	Hierarchical	High	Yes	Good	No	Mod.	High	Active, threshold	No
PEGASIS[23]	Hierarchical	Max.	No	Good	No	High	Low	Chains	No
SOP[24]	Hierarchical	N/A	No	Good	No	Low	High	Routing table	No
GAF[25]	Location/ Hierarchical	Ltd.	No	Good	No	Mod.	Mod.	Virtual grid	No
SPAN[26]	Location/ Hierarchical	Ltd.	Yes	Ltd.	No	Mod	High	Continuously	No
GEAR[27]	Location	Ltd.	No	Ltd	Poss.	Mod.	Mod.	Demand driven	No
SAR[28]	QoS	N/A	Yes	Ltd.	Yes	Low	High	Table driven	Yes
SPEED[29]	QoS	N/A	No	Ltd.	Yes	Mod.	High	Geographic	Yes

Table 1. Classification and Comparison of routing protocols in WSNs.

V. SELECTION OF ROUTING PROTOCOLS FOR WSN APPLICATIONS

Both WSN design space and routing protocol characteristics in WSNs were discussed in last two sections. It is clear that the WSN design space and network architecture affect the WSN routing protocol design. With the knowledge of both the application requirements and routing protocol characteristics, the task for researchers and network engineers in deploying WSNs application with appropriate routing protocols is eased. Table 2 is developed for researchers and network engineers to select appropriate WSN routing protocols based on the application's requirements. The table characterizes and classifies applications' requirements related with routing protocols' characteristics, except last column, which represents the routing protocol selection result for particular application.

Great Duck Island [5] is selected as an example to demonstrate how appropriate routing protocols are selected for a particular application. Firstly, Great Duck is a habitat monitoring application, periodic data delivery is required by this application, and this can be found in data delivery model cell of Great Duck in Table 2, then SPIN, directed diffusion and rumor routing are eliminated for this application because they are event driven and demand driven. Secondly, according to network topology cell of first row in Table 2, Great Duck is deployed as a number of clusters brought together in a star network formation. In addition, nodes are manually placed in several burrows in the island and geographic information is needed to deliver data; this is indicated in data delivery model cell of first row in Table 2, which means a hierarchical and location based protocol are preferred by this application. Based on Table 1, GAF, SPAN and GEAR are location based protocols. Furthermore, GAF and SPAN are also based on hierarchy; this shows GAF and SPAN are selected for the application. Thirdly, the scale of the application is not large, only10-200, which is shown in Table 2. This indicates that both GAF and SPAN are appropriate. Assuming that the scale of the application is large, for example, 200 nodes; SPAN will be eliminated because scalability of SPAN is worse than that of GAF based on observation on both scalability cells of SPAN and GAF in Table 1.

Based on the method presented in this Great Duck example, selection of routing protocols for other applications could also be easily achieved. The last column of Table 2 is the appropriate routing protocols selected for particular WSN applications based on aforementioned methodology. "Application type" column in table 2 lists the application areas like habitat monitoring, environment monitoring, health care, etc. The project column lists the representative project of the particular application areas. Node deployment, topology, data delivery model and data amount are the main factors influencing the selection of routing protocols for WSNs applications. These factors have been specified in the last two sections. The "Size" column here represents network size, which means the number of nodes deployed in the network. The "QoS" column is the specialized quality of service that is required by the application for the data routing such as real-time data, collaborative-processing between neighbor nodes, reliability and so on.

As this paper aims to present a comprehensive methodology to select routing protocols for application in WSNs, only representative applications areas and projects are discussed in this paper.

Application Type	**Project**	**Node Deployment**	**Topology**	**Data delivery Model**	**Size**	**Data amount**	**QoS**	**Routing protocols**
Habitat monitoring	Great Duck [5]	Manual, One time	Cluster-Heads	Periodic, Location-aware	10-100	Minimal	No	SPAN, GAF
Environment Monitoring	PODS Hawaii[6]	Manual, One time	Multi-hop Multi-path	Query-driven,	30-50	Large	Fault tolerance	Directed Diffusion
	Flood Detection [7]	Manual	Multi-hop	Query-driven	200	Minimal	Real-time	COUGAR, ACQUIRE
Health	Artificial Retina[8]	Manual, One time	Cluster-head	Continuously	100	Max.	Real-time	LEACH
	Vital Sign [9]	Manual	Star	Periodic	10-20	Moderate	Real-time	GBR, SAR
Military	Object Tracking [10]	Random	Multi-hop	Location-Awareness	200	Large	Collabrat-Ive	GAF
Home/office	Aware Home[11]	Manual, Iterative	Three-Tiered	Hybrid	20-100	Large	Collabrat-Ive	APTEEN, GEAR
Production/ Commercial	Cold chain [12]	Manual, Iterative	Thee-Tiered	Continuously	55	Moderate	Reliable	SAR

Table 3: Routing protocols selection for particular applications in WSNs

VI. Conclusion

Overall, this paper has presented an informal and comprehensive methodology for researchers and network engineers to select appropriate WSNs routing protocols for particular applications, based on the knowledge of routing protocols and application requirements in WSNs.

WSNs application requirements and routing protocols' characteristics are reviewed in this paper based on WSNs design issues and factors, such as node deployment, scalability, QoS, data delivery model, etc. Based on analyzing the application requirement factors and comparing routing protocols with these factors, appropriate routing protocols for particular applications in WSNs are selected. Finally, a table documenting the selection procedure to determine appropriate routing protocols for particular applications in WSNs is developed. An overview of WSNs is observed after this work. Although many of these routing protocols look promising, there are still many issues that need to be resolved in sensor networks.

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