İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

DYNAMIC THRESHOLD BASED ROUTING FOR SENSOR NETWORKS

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ABBREVIATIONS

LEACH	: Low-energy Adaptive Clustering Hierarchy
TEEN	: Threshold-sensitive Energy Efficient Sensor Network Protocol
APTEEN	: Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network Protocol
TDMA	: Time Division Multiple Access
ELECTION	: Energy-efficient and Low Latency Scheduling Technique for Wireless Sensor Networks

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C_{SG}	: Subgroup Count
T_E	: Effective Timeout
B_L	: Lower Bound
M_H	: Historian Matrix
S_H	: Historian Size
V_S	: Sensed Value
V_{LT}	: Last Transmitted Value
C_C	: Number of Cycles Since the Last Transmission
T_S	: Transmission Time
T_{TE}	: Total Time Elapsed
T_A	: Avarage Periods of Time
C_M	: Absolute value of the minimum change in the sensed values
T_S	: Soft Threshold
B_{HT}	: Hard Threshold Value Bound
V_M	: Maximum value of the transmitted values
T_H	: Hard Threshold
R_1, R_2, R_3, R_4	: Random Number Generators
V_M	: Mean Value of the Uniform Distribution
V_i	: Sensed Value in *i*th Cycle

DUYARGA AĞLARINDA DİNAMİK EŞİK BELİRLEMEYLE YÖNLENDİRME

ÖZET

Duyarga ağları yönlendirme protokolleri, bu ağların limitli enerji seviyeleri, kısıtlı bant genişliği, kısıtlı sistem kaynakları, güvenilir olmayan iletişim ortamı ve hareketlilik gibi çözülmesi gereken sorunları olmasından dolayı ilk kullanılmalarından itibaren hala güncelliğini koruyan geniş bir araştırma alanıdır. Bu protokoller genelde özel olarak belirli ihtiyaçları karşılamak ve belirli uygulamalarda kullanılmak üzere geliştirilmektedirler. En önemli iki duyarga ağı protokol grubu veriye dayalı protokoller ve olay bazlı protokollerdir.

Olay bazlı yönlendirme yapan ağ protokolleri, çevredeki değişimlere daha kısa sürede cevap vermelerinden ve periyodik veri iletim yüklerini taşımamalarından dolayı veriye dayalı yönlendirme yapan ağ protokollerine göre gerçek zamanlı uygulamalara daha uygundurlar. Bu tür protokollerde ortamdan hissedilen verinin iletilme kararının verilmesinde eşik kullanımı yaygın olarak kullanılan bir yöntemdir. Yöntemin verimliliği ise uygulama için doğru eşik değerinin seçilmesine çok bağlıdır. Uygulama alanındaki değişimler olağansa, doğru eşik değerlerini seçmek çok zor değildir ancak ilgilenilen niteliğin değişimi tutarsız ise, eşik değerlerinin sabit olması ihtiyaçları karşılamaktan uzaklaşır.

Bu ihtiyaçlardan hareketle, ortamdan hissedilen niteliğin değişim hızına göre grup bazlı eşik değerleri üreterek değişimlere ayak uydurabilen, duyargaları altgruplara ayırıp, bu alt gruplar üzerinde uyuma çizelgeleri oluşturarak enerji tüketimini artırıp ağ ömrünü uzatan yeni bir olay bazlı ağ yönlendirme protokolü geliştirdik. Yaptığımız testlerde yeni geliştirilen protokol ilgilenilen niteliğin değişimini izleme, yeni koşullara uygun eşik değerleri oluşturma, ağ çalışmasını öngörülemeyen değişimlere göre uygunlaştırma ve düğümler arası haberleşmeyi azaltarak duyarga enerjilerini koruma özellikleri ile varolan protokollerden çok daha iyi bir performans sergilemiştir.

DYNAMIC THRESHOLD BASED ROUTING FOR SENSOR NETWORKS

SUMMARY

Developing wireless sensor network protocols has been a great challenge since first sensor networks were built due to the limitations and problems such as limited energy, limited bandwith, limited system resources, unreliable transmission media and mobility. These protocols are usually developed in order to satisfy different needs and to be used in different applications. Two major groups of them are data-centric and event-based wireless sensor network protocols.

Unlike the data-centric sensor network protocols, event-based protocols are more appropriate for time-critical applications because of having short respond time for the changes of interested parameters and eliminating periodic data acquisition. Thresholds are commonly used to decide to transmit the sensed data on sensor nodes in event-based sensor network protocols. The efficiency of this technique is based on choosing the right thresholds for different applications. If ordinary changes of interests are observed in network environment, it is not so difficult to retrieve efficient thresholds; nevertheless, if the amount of change in the interests is unusual, fixed thresholds would not satisfy the needs.

We propose an event-based sensor network protocol that generates cluster-based thresholds in order to adapt the sensor system to the changes in the environment dynamically and manage sleeping schedules on sensor nodes in subgroups which are formed within clusters in order to provide energy efficiency and increase network lifetimes. Simulation results show that our protocol outperforms existing protocols by observing actual behavior of interested attributes, generating appropriate thresholds, adapting the network to unpredictable changes and increasing network lifetimes by decreasing transmission count between sensor nodes.

1. INTRODUCTION

1.1. Introduction to Wireless Sensor Networks

By the help of improvements in sensor technology, sensor networks have begun to be widely used due to having many advantages. They have a wide range of use on many different applications. On the other hand, sensor networks still have several limitations and problems that result in great research challenges such as energy efficiency and fault tolerance.

Energy efficiency is provided by using different techniques in recent protocols such as sleep scheduling, selective data transmission, data aggregation. In the approach of using thresholds which is implemented to satisfy the needs of time-critical applications, energy efficiency is mostly provided by transmitting sensed data less frequently.

According to a classification methodology [1], which is based on the functionality and application type of the network, sensor networks are grouped in two main families: *Proactive Networks* and *Reactive Networks*. *Proactive Networks* are those networks in which the sensor nodes sense the environment periodically and transmit the data as proposed in LEACH [2]. Nodes in sensor networks of the second group, *Reactive Networks*, sense the environment periodically but transmit the data if there is an interesting change in the value of relevant interest. The networks of this group react immediately to these changes; consequently, these networks are proper for time-critical and real time applications.

Reactive Networks work with the approach of threshold based data transmission. The main concept of threshold based data transmission is to transmit sensed data if the data exceeds predefined and announced static thresholds. Using static thresholds would be efficient if the changes in the interests are usual and the threshold values are well predicted. Nevertheless, when the thresholds are not appropriate for the network, sensor nodes can run out of energy in a short time because of frequent

transmissions or users can not get enough information about the current status of the network because of rare transmissions.

In [3], design and implementation concepts of a reactive network for environmental monitoring are given and the effectiveness of the network for data gathering is measured.

1.2. Objective

In this work, we present a new technique to generate thresholds in order to dynamically adapt the sensor network to the changes in the environment. By using historical data, new thresholds are generated and these values are announced along the network so the network automatically adapts itself to changes. Moreover, by forming subgroups of sensor nodes within clusters and managing sleeping schedules by keeping awake one of the nodes in each subgroups and sleeping the others, transmission count between nodes are decreased. As a result, the network lifetime is increased because only the awake nodes in clusters transmit data and transmissions take place in reasonable intervals; consequently, energy is used optimally. Simulation results show that our algorithm generates near optimal thresholds and helps the nodes in the sensor network to keep up with the changes in the behavior of sensing attributes in the media. Furthermore, network lifetimes increased considerably by eliminating transmissions between sensor nodes that carry redundant data.