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A NOVEL APPROACH FOR ENERGY EFFICIENT TARGET TRACKING IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Nowadays, Wireless sensor networks (WSN) are emerging because of advancement in wireless communication and miniaturization of the hardware. WSN consists of composed of a large number of low-cost, low-power, multifunctional sensor nodes to monitor physical conditions, such as temperature, sound, vibration, pressure, motion and etc. The small sensor nodes used in this network perform sensing, data processing and communicating. They are densely deployed in the desired environment. Recent advancement in wireless communications and electronics has enabled the development of low-cost sensor networks. The sensor networks can be used for various application areas (e.g., health, military, home). For target tracking applications, wireless sensor nodes provide accurate information since they can be deployed and operated near the phenomenon. These sensing devices have the opportunity of collaboration among themselves to improve the target localization and tracking accuracies. An energy-efficient collaborative target tracking paradigm is suitable for wireless sensor networks (WSNs). The lifetime of a Wireless Sensor Network (WSN) is generally limited by the battery lifetime of the sensor nodes. In this respect, efficient monitoring of the entire network's available energy is of great importance to take appropriate preventive actions. However, the physical limitations of WSNs, such as limited memory and energy resources, mandate such a monitoring mechanism to have low complexity and minimum energy dissipation. In this paper, a mutual-information-based sensor selection (MISS) algorithm is adopted for participation in the fusion process. MISS allows the sensor nodes with the highest mutual information about the target state to transmit data so that the energy consumption is reduced while the desired target position estimation accuracy is met. In addition, a novel approach to energy savings in WSNs is devised in the information-controlled transmission power (ICTP) adjustment, where nodes with more information use higher transmission powers than those that are less informative to share their target state information with the neighboring nodes. In this project, a target is accurately effectively tracked in terms of energy by implementing MISS and ICTP algorithm. Simulations using Network Simulator demonstrate the performance gains offered by MISS and ICTP in terms of power consumption and target localization accuracy.

Keywords: WSN, ICTP, power consumption, target tracking networks.

INTRODUCTION

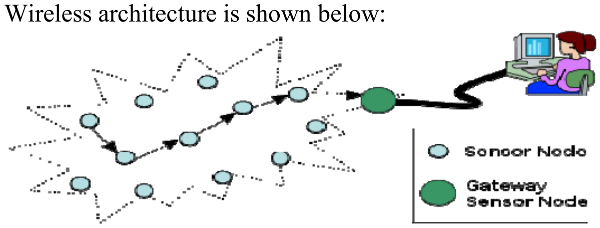
A sensor network is an infrastructure comprised of sensing (measuring), computing and communication elements that gives an administrator the ability to instrument, observe and react to events and phenomena in a specified environment.

Four basics components in a sensor network:

1) an assembly of distributed or localized sensors;
2) an interconnecting network
3) a central point of information clustering;
4) a set of computing resources at the central point to handle data correlation, event trending, status querying, and data mining.

The emerging field of wireless sensor networks combines sensing, computation, and communication into a single tiny device. The power of wireless sensor networks lies in the ability to deploy large numbers of tiny nodes that assemble and configure themselves. Usage scenarios for these devices range from real-time tracking, to monitoring of environmental conditions, to ubiquitous computing environments.

Wireless architecture is shown below:



Sensor node is a node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. The typical architecture of the sensor node is shown in the figure below:

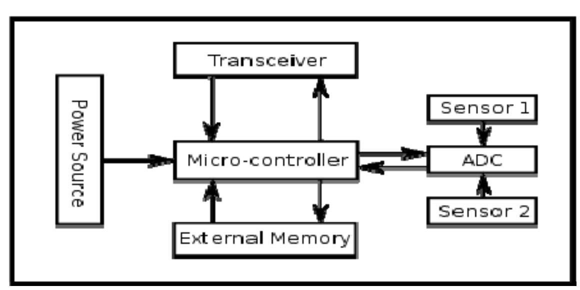


Figure 1: Architecture of sensor node.

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The concept of wireless sensor networks is based on a simple equation:

Sensing + CPU + Radio = Thousands of potential applications.

As soon as people understand the capabilities of a wireless sensor network, hundreds of applications spring to mind. It seems like a straightforward combination of modern technology. Each individual node must be designed to provide the set of primitives necessary to synthesize the interconnected web that will emerge as they are deployed, while meeting strict requirements of size, cost and power consumption. A core challenge is to map the overall system requirements down to individual device capabilities, requirements and actions. To make the wireless sensor network vision a reality, an architecture must be developed that synthesizes the envisioned applications out of the underlying hardware capabilities. To develop this system architecture we work from the high level application requirements down through the low-level hardware requirements. In this process we first attempt to understand the set of target applications. To limit the number of applications that we must consider, we focus on a set of application classes that we believe are representative of a large fraction of the potential usage scenarios. We use this set of application classes to explore the system-level requirements that are placed on the overall architecture. From these system-level requirements we can then drill down into the individual node-level requirements. Additionally, we must provide a detailed background into the capabilities of modern hardware. After we present the raw hardware capabilities, we present a basic wireless sensor node.

TARGET TRACKING

Target-tracking is an important application of wireless sensor network (WSN), where randomly distributed sensor nodes take responsibility for tracking the moving target. The function of each sensor node is to compute the location of target whenever the target is near to it, based on the information obtained from other neighbor sensor nodes. An Energy-based target localization algorithm is used to localize the target.[1]

A sensor uses one type of energy, a signal of some sort, and converts it into a reading for the purpose of information transfer. Each sensor node has multiple modalities for sensing the environment such as acoustic, seismic, light, temperature, etc. However, each sensor can sense only one modality at a time. Sensor networks apply the cooperating ability of sensor nodes. Collaborative detection and tracking requires data exchange between sensor nodes over an ad hoc wireless network with no central coordination medium.

Physical environment can be instrumented with sensor nodes. There are many application areas offered by WSNs. Examples include enemy detection and tracking for military purpose, machine monitoring and inventory control system, remote sensing and environmental monitoring. The sensors are typically battery-powered and have limited wireless communication bandwidth. Therefore, energy efficient target tracking systems are needed for less consumption of important energy from sensors. One of the key advantages of WSNs is the ability to gather certain useful information from the physical world and communicate that information to more powerful devices can process it. If the ability of the WSNs is suitably harnessed, it is envisioned that WSNs can reduce or eliminate the need for human involvement in information gathering in event detection and tracking applications.

The energy constraints are more fundamental than the limited processor bandwidth and memory in sensor networks. There are centralized and distributed approaches for target tracking in WSN. In a centralized target tracking system, sensors in the sensing network detect the target and send the target signatures to the Base Station (BS) that is also a sensor connecting to a laptop or a processing unit. BS determines whether there is a target or not by using the target signatures sent from the sensing nodes and tracks if there is the target. There may be many sensor nodes transporting information to BS at the same time. Therefore, this centralized approach causes the data receiving sensor at BS to die easily because of the information overload. At the same time, the lifetime of the sensor nodes will be get reduced.

To facilitate collaborative data processing for target tracking in sensor networks, the cluster architecture is usually used in which sensors are organized into clusters. Within each cluster, there consists of a cluster head (CH) and several neighboring member sensors. In the conventional cluster architecture, clusters are formed statically at the time of network deployment. The attributes of each cluster, such as the size of a cluster, the area it covers, and the members it possesses, are static. So every node within the cluster will be in active state. So it leads to the wastage of lifetime.

a) Lifetime

Critical to any wireless sensor network deployment is the expected lifetime. The goal of both the environmental monitoring and security application scenarios is to have nodes placed out in the field, unattended, for months or years. The primary limiting factor for the lifetime of a sensor network is the energy supply. Each node must be designed to manage its local supply of energy in order to maximize total network lifetime. In many deployments it is not the average node lifetime that is important, but rather the minimum node lifetime. In the case of wireless security systems, every node must last for multiple years. A single node failure would create vulnerability in the security systems. In some situations it may be possible to exploit external power, perhaps by tapping into building power with some or all nodes. However, one of the major benefits to wireless systems is the ease of installation. Requiring power to be supplied externally to all nodes largely negates this advantage. A compromise is to have a handful of special nodes that are wired into the building's power infrastructure. In most application scenarios, a majority of the nodes will have to be self powered.

They will either have to contain enough stored energy to last for years, or they will have to be able to scavenge energy from the environment through devices, such as solar cells or piezoelectric generators. Both of these options demand that that the average energy consumption of the nodes be as low as possible. The most significant factor in determining lifetime of a given energy supply is radio power consumption. In a wireless sensor node the radio consumes a vast majority of the system energy. This power consumption can be reduced through decreasing the transmission output power or through decreasing the radio duty cycle. Both of these alternatives involve sacrificing other system metrics [2].

Calculation of Lifetime of a Node

In a method of routing data in a mobile ad hoc network, the relay capacity of a node is calculated as the product of the current data rate of the node and the lifetime of the node, in order to determine whether the node will be able to relay the data. The lifetime of the node can be found by dividing the residual energy of the node by the average power consumption of the node [2].

For example: Consider a node with
the following data :
Consumption in sleep-mode:
50 uA = 0,05mA [1u = 10-6]
Consumption while CPU running (for doing calculations): 8mA
Additional consumption for sending (via radio): 10mA
Additional consumption for receiving (via radio): 6mA
The battery provides an amount of energy of 1800 mAh. The node is driven with the same voltage that is provided by the battery.

If it is so then to calculate How long can a node be driven if every 200ms a measurement has to take place but sending is required only once per second ,

We assume that each attempt to send a packet requires to receive one packet as well and that a node knows exactly when a foreign packet will arrive. Each packet consists of 200 bytes of data. The wireless radio connection has a capacity of 9600 bits/s. A single measurement takes 5ms.
Now to find out
(1) How long can a node be driven
(2) To what extend does the lifetime decrease if a node does not know when a packet of another node
arrives and thus has to listen to the radio channel all the time
(3) A couple of influences have not been taken into account in the above calculation. Find some of
them and quote why they shorten or prolong a node's lifetime.

Calculations :
(1) Energy for computation and processing :
5 samples/second x 0,005 seconds (for single measurement) x 8mA = 0,2mAs

Energy for transmission (sending and receiving)
(200 bytes x 8 bit)/(9600 bits/s) x (8mA (basic consumption) + 10 mA (for sending)) +
(200 bytes x 8 bit)/(9600 bits/s) x (8mA (basic consumption) + 6mA (for receiving)) = 2/12s x18 + 2/12x14mA = 5+1/3 mAs
Energy consumption while idle
active time: 0,025s computation and processing 0,333s transmission
Idle time for rest of second (1-0,025-0,333) = 0,641. Idle energy: 0,641s x 0,05 mA = 0,03208 mAs

Energy per second
0,2mAs + 5,33 mAs + 0,03208 mAs = ca. 5,56208 mAs
Battery provides 1800mAh = 1800x60x60 mAs / 5,56208 = ca. 1.165.031s / (60x60x24) = 13,48 days

(2) This time the channel is controlled all the time:
Energy for computation and processing: 5 samples/s x 0,005s x (8+6)mA = 0,35mAs
(here we assume that the node listens to the channel all the time – which is actually the case for most
available hardware. An interrupt will trigger to process an incoming bit. Afterwards normal operation is
resumed).
Energy for transmission (receive): Here receiving is not possible while sending
(200 bytes x 8 bit)/(9600 bits/s) x [(8mA (basic consumption) + 10 mA (for sending)) = 2/12 x18=3 mAs
Energy consumption while idle: (simply replace the sleep consumption by basic
consumption + energy for sending)
active time: 0,025s computation and processing
0,167s transmission
Idle time for rest of second (1-0.025-0.167) = 0,808. Energy: 0.808s x (8+6)mA = 11.31 mAs
Energy per second
0,35mAs + 3 mAs + 11.31 mAs = ca. 14.66 mAs
Battery provides 1800mAh = 1800x60x60 mAs/14.676 = ca. 442,019 seconds / (60x60x24) = ca. 5 days

(3)
- = shorten / + = prolong
Other influences: - Battery does not provide 1.5V all the time
- Energy supply headily depends on temperature
- Routing and accumulation of data was not taken into account
+ Compression of redundant data was not taken into account
- The lifetime of the network in unequal to the lifetime of an average node
If important nodes fail the network can be split into partition which can
communicate no more.

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- Packet collisions / channel noise will cause errors that require retransmission

Now again consider the length of an oscillation should be denoted with lambda. It is known from
communication engineering that a sender's optimal efficiency is achieved if lambda is 1/4
of the oscillation's length. Note that the signal travels approx. at the speed of light (300000
km/s). then to calculate the length of antenna of the sensor node if it sends within the 2.4 GHz
frequency band the solution is :
2.4 GHz means 2.4x109 oscillations/second.
So one oscillation takes 1/2.4x109 seconds. Within this period the radio signal will travel
1/2.4x109 x 300000 km = 12.5 cm
If the antenna is most efficient at a length of ¼ of the oscillation, it should be 3.125 cm

Methods in target tracking

Tracking of a target can be done in two ways:

Query Based Method

The sensor nodes are deployed densely and uniformly in the sensing field, we focus on a scenario that a mobile sink moving through the sensing field queries a specific area or a point of interest for data collection. A *Query* packet is injected by the mobile sink and routed to the specific area, and then the corresponding *Response* packet is returned to the mobile sink via multi-hop communication. Due to the mobility of the sink, the *Query* and *Response* should have different routes. We analyze such a network model to address the problem of efficient data collection in wireless sensor networks and propose an efficient Query-Based Data Collection Scheme (QBDCS). In order to minimize the energy consumption and packet delivery latency, QBDCS chooses the optimal time to send the *Query* packet and tailors the routing mechanism for partial sensor nodes forwarding packets. Simulation results demonstrate that QBDCS completes a query-based data collection cycle with minimum energy consumption and delivery latency.

Sensor networks store data in three places: external, in-network, local. In-network storage allows sensor nodes as storage nodes for sensed data in the sensor network. This form in-network storage in sensor networks is called data centric storage and is achieved by geographic hashing. Geographic hashing refers to hashing of data types to geographic locations. These hashed locations are mapped to nearest sensor nodes as storage points. One interesting observation in geographic hashing is the hashed locations are mapped to static storage nodes, and the mapping is not dependent on query traffic information. If queries are originating from far areas from the given storage node then the amount of traffic generated is high. The traffic can be decreased if the storage nodes are nearer to the query points. This observation leads to propose a location aided storage management in which storage nodes are shifted towards the query regions ie.,'shifting of storage nodes towards the query regions with new query region and storage node formation algorithms'. The improvements are decrease in query traffic and faster retrieval times. This leads to the more energy consumption since every sensor nodes must be active. To overcome this drawback, we can use event based data collection.[4]

Event Based Method

In the wireless sensor network, some nodes can be in the sleep state for extending the lifetime of the sensor nodes. The nodes can be in the semi-sleep state for detecting any event. If any query comes, it becomes active state. By doing the transformation, the life time of the sensor nodes can be increased. For this clustering can be used. **C**lustering sensor nodes into small groups is an effective technique to achieve scalability, self-organization, power saving, channel access, routing, etc. Sensors within a cluster are expected to be communicating with a cluster head only. The cluster heads summarize and process sensor data from the clusters and maintain the link with the base station. The clustering is driven by the minimization of energy for all the sensors.

Achieving energy efficiency to prolong the network lifetime is an important design criterion for wireless sensor networks. In this paper, we propose a novel approach that exploits the broadcast nature of the wireless medium for energy conservation in spatially correlated wireless sensor networks. Since wireless transmission is inherently broadcast, when one sensor node transmits, other nodes in its coverage area can receive the transmitted data. When data collected by different sensors are correlated, each sensor can utilize the data it overhears from other sensors to compress its own data and conserve energy in its own transmissions. This idea is applied to a class of cluster-based wireless sensor networks in which each sensing node transmits collected data directly to its cluster head using time division multiple access (TDMA).[7] The lifetime optimization problem can be solved by a sequence of linear programming problems. It is also proposed a heuristic scheme, which has low complexity and achieves near optimal performance. Important characteristics of wireless sensor networks such as node startup cost and packet loss due to transmission errors are also considered. Numerical results show that by exploiting the broadcast nature of the wireless medium, our control schemes achieve significant improvement in the sensors' lifetimes.[5]

SIMULATION RESULT

The following diagram shows the graph graph between Energy consumed and mean error and the graph between mean error .sensors nodes are selected to cooperate according to the mutual information measure. Sensor queries are routed with one hop distance.

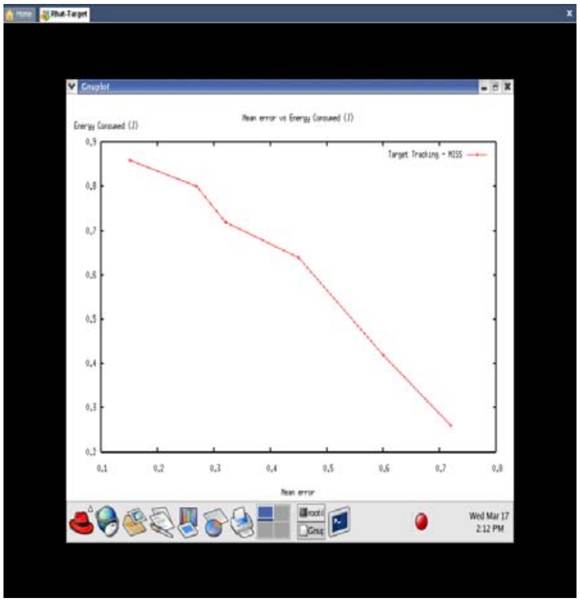

Figure 2: Graph between energy consumed and mean error.

Moreover, the sensor network queries are to be routed within one-hop distance.

Power adjustment scheme for the transmission power is employed.

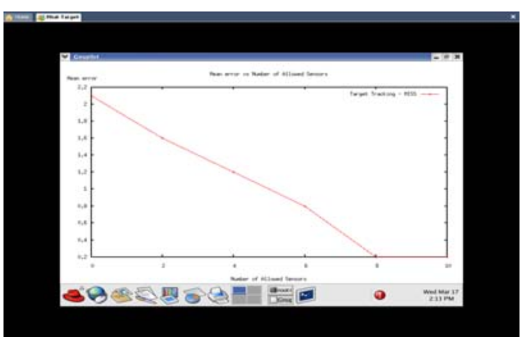

Figure 3: Graph between mean error and number of allowed sensors

It is generally assumed that all sensor nodes send reliable data to network that all sensor nodes send reliable data to the network

CONCLUSIONS

A mutual information-based measure is adopted to select the most informative subset of the sensor nodes to actively participate in the distributed data fusion framework, where the duty of the WSN is to accurately localize and track the targets. The DDF architecture takes advantage of the long communication range of the wireless sensor devices, relative to their sensing range, and facilitates a sensor node to update its belief about the current state of the target. With the detection reports from its neighbors, a belief update takes place even if the sensor is not detecting the target. The information obtained from the neighboring nodes about an approaching target before it is sensed reduces the target localization error by improving the target state filtering performance. A new communication transmission power adjustment scheme is proposed to further improve the energy savings while preserving the tracking quality constraints. Sensor nodes adjust their transmission powers in proportion to their knowledge: those that know more about the target state should use more power to share their information. Tests indicate that the performance of the proposed power adjustment scheme depends on the network querying technique. If the application is delay-sensitive and needs an immediate response from the network, any sensor node in the WSN can respond right away to the query with an acceptable target localization error. If the application can tolerate some delay and has strict target localization error constraints, querying improves the target localization performance [6]. The proposed Information-Controlled Transmission Power adjustment scheme improves the energy savings while preserving the desired target tracking accuracy when the most informative node is queried. However, querying any sensor node, while reducing the transmission powers of the less informative sensor nodes, ends up with drastically worse target tracking accuracies. For the cases studied, simulation results show that 75 percent energy savings can be achieved for a given tracking quality by selecting the sensor nodes to cooperate according to the mutual information measure. Moreover, if the sensor network queries are to be routed within one-hop distance of the query entry node, 2.34 times more energy savings compared to the no power adjustment scheme can be achievable by adjusting the communication transmission powers of the sensor nodes. It is generally assumed that all sensor nodes send reliable data to the network. In the future work, the detection of faulty and outlier sensor nodes in the network, and possible precautions that can be taken against them, will be investigated. In addition, the presence of multiple targets brings along challenges with measurement-to-measurement association, measurement-to-track association, track-to-track association, and track-to-sensor association. In the multiple target case, sensor nodes would report only about the target which they were associated to. Hence, the communication transmission power can be adjusted according to the information about the target from which the sensor node is responsible for reporting.

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