

Real Time Communication In Sensor Networks

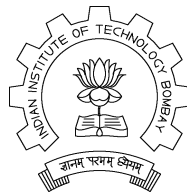
Qos Seminar Report

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Abstract

Wireless Sensor networks represent a new generation of Real-time systems with different communication constraints from traditional systems. This report includes the basic Sensor Network Communication Architecture, and Design factors for such an architecture. We also discuss a new protocol called **SPEED**, which provides real-time communication services, like real-time unicast, real-time area-multicast and real-time area-anycast. This protocol is stateless and use a localized algorithm which results in minimal control overhead.

Chapter 1

Introduction to Sensor Networks

Sensor networks are being extensively used in military, medical and industrial applications. Monitoring of safety critical systems, smart systems, chemical, radiological and biological detection, domestic security systems like intruder detection systems all use sensor networks.

Sensor networks are composed of many sensor nodes. They are deployed in the environment to be sensed and controlled. Each sensor node is capable of communicating with other sensor nodes. But generally sensor nodes are limited in memory, power and computational ability. Thus they can only transmit data to a limited distance.

A sensor field is an area which contains many sensor nodes doing the same work [3]. The sensor field can be densely populated. The typical job of a sensor node is to sense the environment, collect data and route the data to the sink (as shown in Figure 1.1). The data is routed to the main center by a multi-hop infrastructure-less network through the sink.

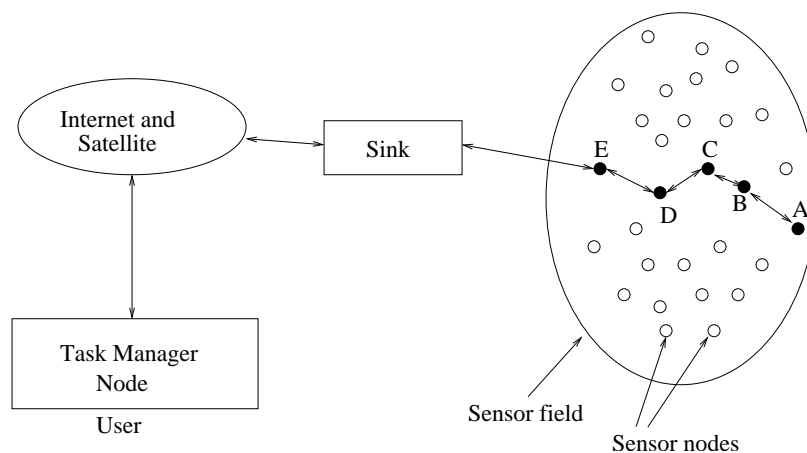


Figure 1.1: Sensor nodes in Sensor Fields

Chapter 2

Issues in Communication between Sensor Networks

Sensor networks are a special class of ad-hoc mobile networks [1]. Hence they require different communication protocols tailor-made for them.

The key issues in the design of sensor networks that affect the communication between various sensor nodes are [1]:

- Data Centric Paradigm
- Location Based
- Real Time
- Scalability
- Fault Tolerance
- Resource Constraints

2.1 Data Centric Paradigm

Traditional networks put more emphasis on addressing and use addresses to route data. The data is communicated between two systems through a route which contains two or more addressed nodes.

In contrast sensor networks are intrinsically data-centric [3]. Data from various sources, sensing the same event in the same environment, must be aggregated. This does not give specific importance to any individual sensor node. Messages are not sent to individual nodes but rather to locations or areas based on data content.

Hence it is important that the routing protocols used to route data take this data centric paradigm into consideration.

2.2 Location Based

Sensor networks deal with physical environments and hence must work with physical locations rather than logical IDs. Infact sensor networks do not have permanent IDs assigned to them. One of the reasons is the sheer volume of sensor networks existing globally and the constraint on their memory and processing capabilities.

Thus any query must refer to location rather than to a particular ID. When such a query is put forth, the local nodes execute the query individually and these individual results are aggregated.

Hence the need for data centric and location based protocols [8].

2.3 Real Time

Sensor networks are deployed in environments dealing with real world events. Hence there is a necessity for real time guarantees for communication and data transfer.

For instance a sensor network may be deployed in a nuclear plant and its function is to detect radioactive leakage. If we cannot guarantee that within a certain interval of detection of leakage, the safety systems are not alerted then there may be a catastrophe.

Many protocols that can deal with real-time nature of sensor network have to be designed.

2.4 Scalability

When the sensor network is designed to be scalable, the communication protocols must maintain minimum global state and incur as little control overhead as possible. It must easily work with highly dense sensor networks.

2.5 Fault Tolerance

Sensor nodes are highly susceptible to failures. These failures may be due to environmental noise or obstacles. Or they may be due to wear and tear, power depletion, physical destruction.

The protocols must be such that the sensor network performs properly in the event of failure of many nodes. They must be able to self stabilize.

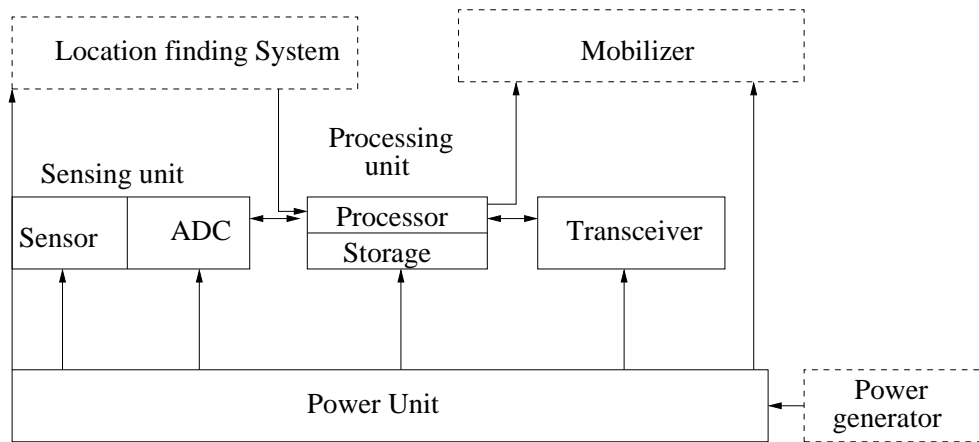


Figure 2.1: The basic components of Sensor Node

2.6 Hardware Constraints

This is the crucial design factor as it defines the efficiency of a node. Each node primarily comprises of the following components (Figure 2.1).

- **Sensing unit** Used to convert analog signals to digital signals which are generated by sensor nodes
- **Processing unit** Used to manage the functions that are responsible for communicating with the other sensor nodes. This unit is usually associated with the small storage capacity.
- **Transceiver unit** Used to connect a node to the sensor network.
- **Power unit** This is the heart of the node which determines the life time of a sensor node. Power can be saved by switching off the node when not necessary and bringing up only when needed. It can also use solar energy for charging itself.
- **Mobilizer** A mobilizer is needed in cases where a sensor node has to move from one location to another.

2.7 Resource Constraints

Sensor networks use small batteries to operate and radio transmissions take up most of this power. Hence power conservation is the key issue in sensor networks, especially at the communication layer. Energy efficient routes can be found based on available power in the nodes or the energy required for transmission in the links along the routes. An energy efficient route can be selected either by selecting a route which has the maximum available power among all nodes or selecting the route that consumes minimum energy to transmit data from the node to the destination in the route or by selecting a minimum hop route or by selecting a route in which the minimum power is larger than the minimum powers of the other routes.

Chapter 3

Protocol Stack and Routing Protocols

3.1 Sensor network Protocol stack

The protocol stack for such a network is similar to ordinary network except that it includes 3 planes termed as Task management plane, Mobility management plane and Power management plane as shown in figure 3.1. The following section provides the functionality of each layer.

3.1.1 Physical layer

The physical layer has to determine a good modulation scheme which is critical for reliable communication. It is also responsible for frequency selection, signal detection, carrier generation and data encryption. Ultra Wide Band(UWB) or Impulse Radio(IR) has been used for communication. UWB uses baseband transmissions and thus requires no intermediate carrier frequencies. It also requires low transmission power and simple circuitry.

3.1.2 Data link layer

The data link layer is responsible for multiplexing of data streams, data frame detection, medium access and error control. The goals of a MAC protocol in a self organizing sensor network is to create network infrastructure and to fairly share resources among the nodes in the network.

We cannot use the existing MAC designs because of the difference in the area of concentration between ordinary networks and sensor networks. For example in case of Cellular networks the mobile node is always one hop away from the base station and the base station has infinite resources with it whereas in sensor networks there is no central station. Another example will be Mobile Ad-hoc networks which are somewhat closely related to sensor networks. In MANET's the task of the MAC protocol is to form a network infrastructure and maintain it in the case of mobility. The nodes are basically equipped with portable battery but they can be manually replaced which is not at all the case with the sensor networks.

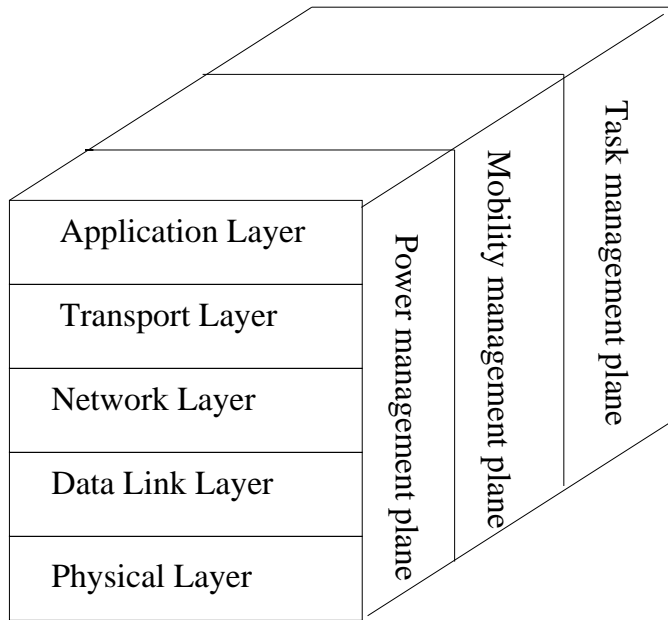


Figure 3.1: The Protocol Stack

Self-Organizing MAC(SMACS) and Eaves drop-And-Register(EAR) Algorithm

The purpose of SMACS is to startup the network and link layer functionalities. The EAR algorithm will take care of seamless connection of mobile nodes in the sensor network. In SMACS the neighbor discovery and channel assignment phases are combined so that the nodes might have formed a connected network by the time they hear from all their neighbors. Since the available bandwidth is more than the maximum data rate we can use a pair of time slots operating at random but at fixed frequency in the link. The sole advantage is removal of network wide synchronization.

EAR algorithm works transparently to SMACS which is functional until the introduction of mobile nodes into the network. The EAR algorithm doesn't guarantee but attempts to provide a continuous service to the mobile nodes under both stationary and moving conditions.

Ways of saving Power

Whatever the MAC protocol used, the effective operation of a sensor node depends on the amount of power that is available with the node. One quick solution seems to be turning off the power of transceiver when it is not required. In order to make it energy efficient we should turn off only if the time exceeds a certain threshold otherwise the energy required to start up will be more than the energy that it might have spent if it would have been on.

3.1.3 Network Layer

The following are the important criteria that should taken into consideration while designing a network protocol.

- Efficiency in usage of power should be given utmost importance
- Sensor networks are mostly data-centric

- Data aggregation can be done if it doesn't affect the collaborative effort of the sensor nodes.
- A sensor network is addressed based on attribute and location awareness and not by a globally unique id.

As sensor networks are mostly data-centric, the interest dissemination is done either by the sink or by the sensor nodes which broadcasts when it has data and waits for a response from the interested nodes.

Sequential Assignment Routing

SMACS is used to enable a sensor node to discover its neighbors and establish transmission/reception schedules without the need of a centrally governing station. Once the mobile nodes come into the network the EAR algorithm will provide seamless interconnection to the nodes. The EAR algorithm is based on invitation messages and registration messages by stationary nodes by mobile nodes. In SAR algorithm, a tree with each neighbor as root which is one-hop neighbor from the sink is generated. The tree will be formed by avoiding the nodes which have less QoS and low energy reserves.

Once such trees are generated, some nodes will be a part of many trees which allows the node to pick one tree to send data to the destination. The SAR algorithm selects a tree on the basis of Energy resources which defines the number of packets that a node can send if the node has is exclusively using the path and additive QoS metrics which determine the QoS requirements and also priority level.

3.1.4 Transport layer

Basically the connection between the sink and the central authority may be either TCP/UDP but the communication between the sensor nodes to the sink and among the sensor nodes only UDP can be used. So in Sensor networks the communication is not end-to-end and so they are not based on Global addressing as IP addresses in Internet. Basically they are identified by using attribute-based naming to address the destinations for data packets.

3.1.5 Application Layer

The following are the various application layer protocols that can be used in Sensor nodes

- Sensor Management Protocol(SMP)
- Task Assignment and Data Advertisement Protocol(TADAP)
- Sender Query and Data Dissemination Protocol(SQDDP)

Sensor Management Protocol

This application protocol is used by the System Administrators to interact with the Sensor Networks. Since sensor networks don't have Global Identification, they can be accessed using attribute-based naming and location addressing which are used for doing the following tasks like Moving Sensor nodes, Turning Sensor nodes on and off, Authentication and Security in data communications and many more.

TADAP

Most important activity in Sensor networks is how interest can be sent to the nodes or subset of nodes or to the whole network. One way is to inform the nodes that i have data and wait for response from the interested node. Another way is to send our interests to the user and let the user query at his interest.

SQDDP

SQDDP basically provides interfaces for users to query the network and to receive the replies from the network. Queries will not be towards a particular node but location based or attribute based. "location of the nodes that sense pressure > 5 atmospheres" is an example for attribute based query and "pressure read by the nodes at region A" is an example of location based query.

3.2 Routing Protocols

There are numerous ad hoc routing protocols are broadly categorized into flat routing and hierarchical routing. In flat routing, every route has equal responsibility of maintaining routing information. Routing algorithms in this category can be further classified into :

- **Proactive Routing** These algorithms maintain routes continuously for all reachable nodes. They require periodic dissemination of routing updates.
- **Reactive Routing** These algorithms establish and maintain nodes only if they are needed for communication. New routes are acquired when a new connection is set up and is to be maintained throughout the lifetime of the connection despite of topology changes.
- **Geographic routing** Geographic routing protocols utilize locations for routing decisions[4].

Chapter 4

SPEED - A Real Time Protocol for Communication

SPEED is a real-time communication protocol for sensor networks[7]. It provides 3 types of real-time communication services, namely, real-time unicast , real-time area-multicast and real-time area-anycast.

In real-time unicast data is sent to a specific sensor node (Data sent to Base Station from a sensor node). In real-time area-multicast data is sent to an area in the sensor network (Base station queries an area). In real-time area-anycast the destination is any one node in an area.

SPEED supports soft real-time based on feedback control and stateless algorithms. SPEED utilizes geographic location to make localized routing decisions. But SPEED also handles congestion and provides soft real-time which location based protocols do not. Route discovery broadcasts in reactive routing algorithms can lead to significant delays in sensor networks. This makes on-demand algorithms less suitable for real-time applications.

SPEED maintains only immediate neighbor information. It does not maintain a routing table nor per-destination states. Hence it's memory requirements are minimum.

SPEED does not use any information related to deadlines. Instead it provides real-time guarantees by providing a uniform packet delivery speed across the sensor network so that the end-to-end delay of the packet is proportional to the distance between the source and destination.

SPEED does not require specialized MAC support and can work with existing best effort MAC protocols due the feedback control scheme that it employs. All distributed operations in SPEED are highly localized meaning that any action invoked by a node will not affect the system as a whole.

Chapter 5

Conclusion

Sensor Networks are different from other ad hoc networks and hence require specialized protocols for communication. To provide real-time guarantees the protocol must be specifically designed with real-time guarantees in mind.

We have briefly introduced the communication in a Sensor network and have presented various issues that affects for real time communication in such networks. We have discussed the basic architecture of a Sensor Network and looked at various categories of routing protocols. We have also discussed a protocol called SPEED, which guarantees soft-real time guarantees and hence is very much suitable for real-time communication in sensor networks.

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