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A STUDY OF WIRELESS SENSOR NETWORKS ARCHITECTURE &ITS PROTOCOLS

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Abstract:-

Wireless sensor networks consist of individual nodes that are able to interact with the environment by sensing or controlling physical parameters. These nodes have to collaborate to fulfill their tasks. The nodes are interlinked together and byusing wireless links each node is able to communicate and collaborate with each other.

An ad hoc network is a network that is setup, literally, for a specific purpose, to meet a quickly appearing communication need.

The simplest example of an ad hoc network is perhaps a set ofcomputers connected together via cables to form a small network, like a few laptops in a meetingroom.

In this example, the aspect ofself-configurationis crucial – the network is expected to workwithout manual management or configurationUsually, however, the notion of a MANET is associated with wireless communication and specifically wireless multichip communication; also, the name indicates the mobility of participating nodes as a typical ingredient.

On the other hand, these mechanisms also have to generalize to awider range of applications lest a completefrom-scratch development and implementation of a WSN becomes necessary for every individual application this would likely render WSNs as a technological concept economically infeasible

Keywords: - Wireless, Sensor, Networks, Ad hoc, Architecture, Protocols.

1. INTRODUCTION

Building a wireless sensor network first of allrequires the constituting nodes to be developed andavailable. These nodes have to meet the requirements that come from the specific requirements of agiven application: they might have to be small, cheap, or energy efficient, they have to be equippedwith the right sensors, the necessary computation and memory resources, and they need adequatecommunication facilities. There are four basic components in a sensor network: (1) an assembly of distributed or localized sensors; (2) an interconnecting network (usually, but not always,wireless-based); (3) a central point of information clustering; and (4) a set of computing resources at the central point (or beyond) to handle data correlation, eventtrending, status querying, and data mining. In this context, the sensing and computation nodes are considered part of the sensor network; in fact, some of the computingmay be done in the network itself. Because of the potentially large quantity of datacollected, algorithmic methods for data management play an important role in sensor networks. The computation and communication infrastructure associated withsensor networks is often specific to this environment and rooted in the deviceand application-based nature of these networks. For example, unlike most other settings, in-network processing is desirable in sensor networks; furthermore, nodepower (and/or battery life) is a key design considerationWhen choosing the hardware components for a wireless sensor node, evidently the application’srequirements play a decisive factor with regard mostly to size, costs, and energy consumption of thenodes – communication and computation facilities as such are often considered to be of acceptablequality, but the trade-offs between features and costs is crucial. A basic sensor node comprises five main components:

Controller: -A controller to process all the relevant data, capable of executing arbitrary code.

Memory: -Some memory to store programs and intermediate data; usually, different types of memoryare used for programs and data.

Sensors and actuators: -The actual interface to the physical world: devices that can observe orcontrol physical parameters of the environment.

Communication: - Turning nodes into a network requires a device for sending and receiving information over a wireless channel.

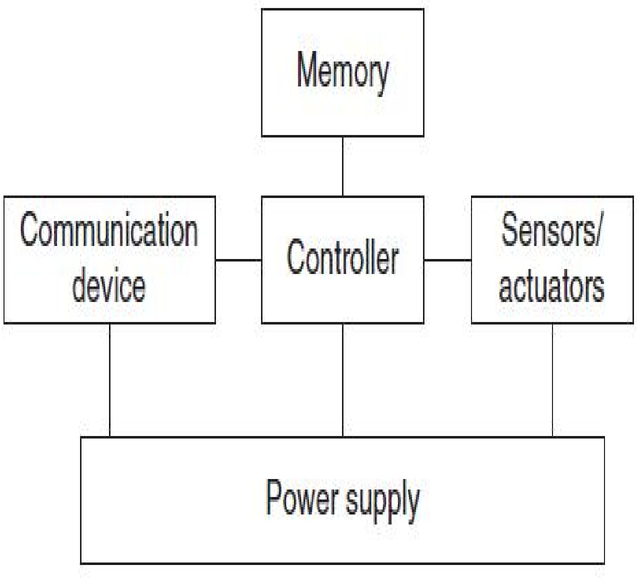

Figure 1.1: Sensor node hardware components

Power supply: - As usually no tethered power supply is available, some form of batteries is necessaryto provide energy. Sometimes, some form of recharging by obtaining energy from theenvironment is available as well. Each of these components has to operate balancing the trade-off between as small energyconsumption as possible on the one hand and the need to fulfill their tasks on the other hand.For example, both the communication device and the controller should be turned off as long aspossible. To wake up again, the controller could, for example, use a preprogrammed timer to bereactivated after some time. Alternatively, the sensors could be programmed to raise an interrupt if a given event occurs – say, a temperature value exceeds a given threshold or the communicationdevice detects an incoming transmission. Supporting such alert functions requires appropriate interconnection between individual components.Moreover, both control and data information hasto be exchanged along these interconnections.This interconnection can be very simple. Power efficiency in WSNs is generally accomplished in three ways:

1.Low-duty-cycle operation.

2.Local/in-network processing to reduce data volume (and hence transmissiontime).

3. Multihop networking reduces the requirement for long-range transmissionsince signal path loss is an inverse exponent with range or distance. Eachnode in the sensor network can act as a repeater, thereby reducing the linkrange coverage required and, in turn, the transmission power. Conventional wireless networks are generally designed with link ranges on theorder of tens, hundreds, or thousands of miles. The reduced link range and the compressed data payload in WSNs result in characteristic link budgets that differ fromthose of conventional systems.

2. WSN ARCHITECTURE

Several typical interaction patterns found in WSNs – event detection,periodic measurements, function approximation and edge detection, or tracking – it has also alreadybriefly touched upon the definition of "sources" and "sinks". A source is any entity in the networkthat can provide information, that is, typically a sensor node; it could also be an actuator node thatprovides feedback about an operation. A sink, on the other hand, is the entity where information is required. There are essentially threeoptions for a sink: it could belong to the sensor network as such and be just another sensor/actuatornode or it could be an entity outside this network.

For this second case, the sink could be an actualdevice, for example, a handheld or PDA used to interact with the sensor network; it could alsobe merely a gateway to another larger network such as the Internet, where the actual request forthe information comes from some node "far away" and only indirectly connected to such a sensornetwork. These main types of sinks are illustrated by Figure

2.1, showing sources and sinks indirect communication.

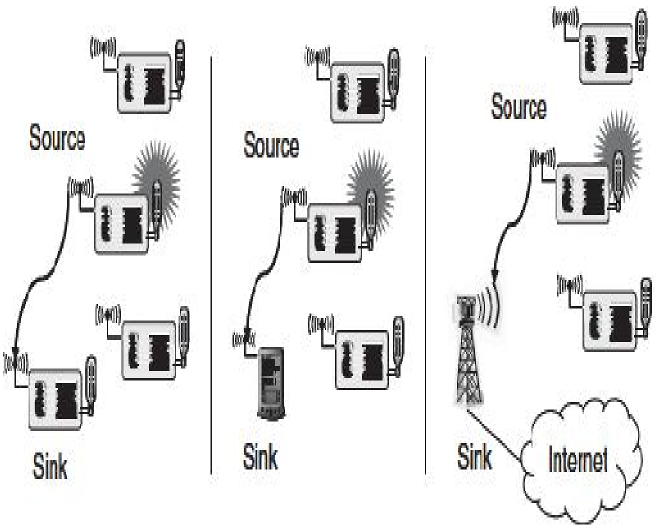

Figure 2.1: Single hop sensor networks

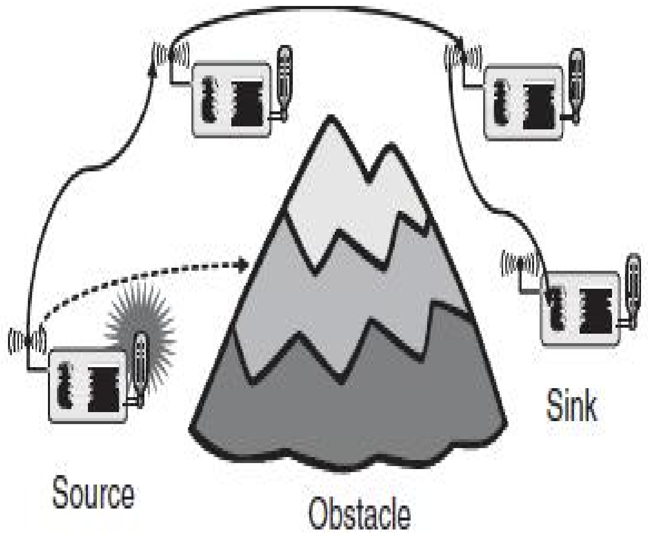

Figure 2.2: Multihop sensor networks

To overcome such limited distances, an obvious way out is to use relay stations, with thedata packets taking multi hops from the source to the sink. This concept of Multihop networks(illustrated in Figure 2.2) is particularly attractive for WSNs as the sensor nodes themselves canact as such relay nodes, foregoing the need for additional equipment. Depending on the particularapplication, the likelihood of having an intermediate sensor node at the right place can actuallybe quite high – for example, when a given area has to be uniformly equipped with sensor nodesanyway – but nevertheless, there is not always a guarantee that such Multihop routes from sourceto sink exist, nor that such a route is particularly short.

2.1. Types of Mobility in WSNs

In the scenarios discussed above, all participants were stationary. But one of the main virtues ofwireless communication is its ability to support mobile participants. In wireless sensor networks,mobility can appear in three main forms:

Node mobility: - The wireless sensor nodes themselves can be mobile. The meaning of such mobilityis highly application dependent. In examples like environmental control, node mobility shouldnot happen; in livestock surveillance (sensor nodes attached to cattle, for example), it is thecommon rule. In the face of node mobility, the network has to reorganize itself frequently enough to beable to function correctly. It is clear that there are trade-offs between the frequency andspeed of node movement on the one hand and the energy required to maintain a desiredlevel of functionality in the network on the other hand.

Sink mobility: - The information sinks can be mobile (Figure 2.3). While this can be a special caseof node mobility, the important aspect is the mobility of an information sink that is not partof the sensor network, for example, a human user requested information via a PDA whilewalking in an intelligent building. In a simple case, such a requester can interact with the WSN at one point and completeits interactions before moving on. In many cases, consecutive interactions can be treated asseparate, unrelated requests. Whether the requester is allowed interactions with any node oronly with specific nodes is a design choice for the appropriate protocol layers.

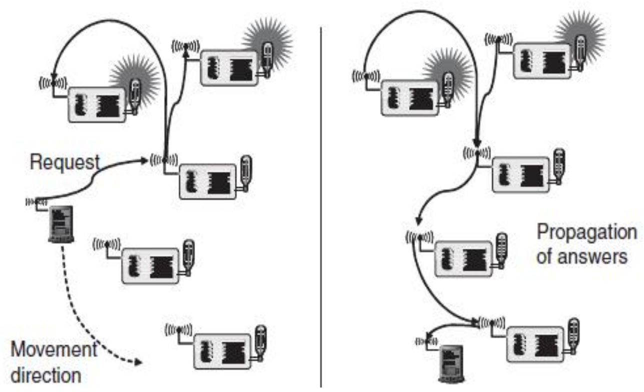

Figure 2.3: Mobility of nodes

Event mobility: - In applications like event detection and in particular in tracking applications, thecause of the events or the objects to be tracked can be mobile. In such scenarios, it is (usually) important that the observed event is covered by a sufficientnumber of sensors at all time. Hence, sensors will wake up around the object, engagedin higher activity to observe the present object, and then go back to sleep. As the eventsource moves through the network, it is accompanied by an area of activity within thenetwork – this has been called the frisbeemodel Communication protocols for WSNs will have to render appropriate support for these forms ofmobility. In particular, event mobility is quite uncommon, compared to previous forms of mobileor wireless networks.

2.3. WSN Design Principles

Appropriate QoS support, energy efficiency, and scalability are important design and optimizationgoals for wireless sensor networks. But these goals themselves do not provide many hints on how tostructure a network such that they are achieved. A few basic principles have emerged, which can beuseful when designing networking protocols; the description here follows partially references [246,699]. Nonetheless, the general advice to always consider the needs of a concrete application holdshere as well – for each of these basic principles, there are examples where following them wouldresult in inferior solutions.

Both the scalability and the robustness optimization goal, and to some degree also the other goals,make it imperative to organize the network in a distributed fashion. That means that there shouldbe no centralized entity in charge – such an entity could, for example, control medium access ormake routing decisions, similar to the tasks performed by a base station in cellular mobile networks. The disadvantages of such a centralized approach are obvious as it introduces exposed points offailure and is difficult to implement in a radio network, where participants only have a limitedcommunication range. Rather, the WSNs nodes should cooperatively organize the network, usingdistributed algorithms and protocols.

Self-organization is a commonly used term for this principle. When organizing a network in a distributed fashion, it is necessary to be aware of potentialshortcomings of this approach. In many circumstances, a centralized approach can produce solutionsthat perform better or require fewer resources (in particular, energy). To combine the advantages,one possibility is to use centralized principles in a localized fashion by dynamically electing, outof the set of equal nodes, specific nodes that assume the responsibilities of a centralized agent, forexample, to organize medium access. Such elections result in a hierarchy, which has to be dynamic:

The election process should be repeated continuously lest the resources of the elected nodes beovertaxed, the elected node runs out of energy, and the robustness disadvantages of such – even onlylocalized – hierarchies manifest themselves. When organizing a network in a distributed fashion, the nodes in the network are not only passingon packets or executing application programs, they are also actively involved in taking decisionsabout how to operate the network. This is a specific form of information processing that happensin the network, but is limited to information about the network itself. It is possible to extend thisconcept by also taking the concrete data that is to be transported by the network into account inthis information processing, making **in-network processing** a first-rank design principle.

3. WSN MAC PROTOCOLS

The physical layer is mostly concerned with modulation and demodulation of digital data; this taskis carried out by so-called transceivers. In sensor networks, the challenge is to find modulationschemes and transceiver architectures that are simple, low cost, but still robust enough to providethe desired service.WSNs are typically composed of a large number of low-cost, low-power, multi-functional wireless devices deployed over a geographical area in an ad hocfashion and without careful planning. Individually, sensing devices are resource-constrained and therefore are only capable of a limited amount of processing and communication. This section provides the necessary background on wireless channels and digital communicationover these. This is by no means an exhaustive discussion; it should just provide enough backgroundand the most important notions to understand the energy aspects involved.

Communication among wireless sensor nodes is usually achieved by means of aunique channel. It is the characteristic of this channel that only a single node cantransmit a message at any given time. Therefore, shared access of the channelrequires the establishment of a MAC protocol among the sensor nodes. The objective of the MAC protocol is to regulate access to the shared wireless medium such thatthe performance requirements of the underlying application are satisfied [5.4–5.7]. From the perspective of the Open Systems Interconnection (OSI) Reference Model(OSIRM), the MAC protocol functionalities are provided by the lower sublayer ofthe data link layer (DLL). The higher sublayer of the DLL is referred as the logical link control (LLC) layer. The subdivision of the data link layer into two sublayers isnecessary to accommodate the logic required to manage access to a shared accesscommunications medium. Furthermore, the presence of the LLC sublayer allowssupport for several MAC options, depending on the structure and topology of thenetwork, the characteristics of the communication channel, and the quality of service requirements of the supported application.

3.2. Fundamentals of MAC

One major difficulty in designing effective MAC protocols for shared access mediaarises from the spatial distribution of the communicating nodes [5.8]. To reachagreement as to which node can access the communication channel at any giventime, the nodes must exchange some amount of coordinating information. Theexchange of this information, however, typically requires use of the communicationchannel itself. This recursive aspect of the multiaccess medium problem increasesthe complexity of the access control protocol and consequently, the overheadrequired to regulate access among the competing nodes. Furthermore, spatial distribution does not allow a given node on the network to know the instantaneousstatus of other nodes on the network. Any information explicitly or implicitly gathered by any node is at least as old as the time required for its propagation throughthe communication channel. Two main factors, the intelligence of the decision made by the access protocoland the overhead involved, influence the aggregate behavior of a distributed multiple-access protocol. These two factors are unavoidably intertwined. An attempt toimprove the quality of decisions does not necessarily reduce the overhead incurred. On the other hand, reducing the overhead is likely to lower the quality of the decision. Thus, a trade-off between these two factors must be made.

4. COMMON PROTOCOLS

MAC-layer protocols [5.44]. The first source of energy waste iscollision, whichoccurs when two or more sensor nodes attempt to transmit simultaneously. Theneed to retransmit a packet that has been corrupted by a collision increases energyconsumption. The second source of energy waste is idle listening. A sensor nodeenters this mode when it is listening for a traffic that is not sent. This energyexpended monitoring a silent channel can be high in several sensor network applications. The third source of energy waste isoverhearingwhich occurs when a sensornode receives packets that are destined to other nodes. Due to their low transmitteroutput, receivers in sensor nodes may dissipate a large amount of power. The fourthmajor source of energy waste is caused bycontrol packet overhead. Control packetsare required to regulate access to the transmission channel. A high number of controlpackets transmitted, relative to the number of data packets delivered indicates lowenergy efficiency. Finally,frequent switchingbetween different operation modesmay result in significant energy consumption. Limiting the number of transitionsbetween sleep and active modes, for example, leads to considerable energy saving. Energy-efficient link-layer protocols achieve energy savings by controlling theradio to eliminate, or at least reduce, energy waste caused by the sources notedabove. Further energy gains can be achieved using comprehensive energy management schemes which focus not only on the sensor node radio, but equally important,on other sources of energy consumption. The choice of the MAC method is the major determining factor in the performanceof a WSN. Several strategies have been proposed to solve the shared medium accessproblem. These strategiesattempt, by various mechanisms, to strike a balancebetween achieving the highest-quality resource allocation decision and the overhead necessary to reach this decision. These strategies can be classified in threemajor categories: fixed assignment, demand assignment, and random assignment.

1. **FDMA.**
2. **TDMA.**
3. **CDMA.**
4. **CSMA.**

In location-based protocols, sensor nodes are addressed by means of their locations. Location information for sensor nodes is required for sensor networks by most of the routing protocols to calculate the distance between two particular nodes so that energy consumption can be estimated. In this section, we present a sample of location-aware routing protocols proposed for WSNs.

Geographic Adaptive Fidelity (GAF):

GAF [15] is an energy-aware routing protocol primarily proposed for MANETs, but can also be used for WSNs because it favors energy conservation. The design of GAF is motivated based on an energy model [16, 17] that considers energy consumption due to the reception and transmission of packets as well as idle (or listening) time when the radio of a sensor is on to detect the presence of incoming packets.

Coordination of Power Saving with Routing:

Span [21,22] is a routing protocol also primarily proposed for MANETs, but can be applied to WSNs as its goal is to reduce energy consumption of the nodes. Span is motivated by the fact that the wireless network interface of a device is often the single largest consumer of power. Hence, it would be better to turn the radio off during idle time. Although Span does not require that sensors know their location information, it runs well with a geographic forwarding protocol.

Trajectory-Based Forwarding (TBF):

TBF [23] is a routing protocol that requires a sufficiently dense network and the presence of a coordinate system, for example, a GPS, so that the sensors can position themselves and estimate distance to their neighbors. The source specifies the trajectory in a packet, but does not explicitly indicate the path on a hop-by-hop basis. Based on the location information of its neighbors, a forwarding sensor makes a greedy decision to determine the next hop that is the closest to the trajectory fixed by the source sensor.

Hybrid, Energy-Efficient Distributed Clustering (HEED):

HEED [40, 41] extends the basic scheme of LEACH by using residual energy and node degree or density as a metric for cluster selection to achieve power balancing. It operates in multi-hop networks, using an adaptive transmission power in the inter-clustering communication.

CONCLUSION

One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the scarce energy resources of sensors. The ultimate objective behind the routing protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. The energy consumption of the sensors is dominated by data transmission and reception. Therefore, routing protocols designed for WSNs should be as energy efficient as possible to prolong the lifetime of individual sensors, and hence the network lifetime. In this paper, we have surveyed a sample of routing protocols by taking into account several classification criteria, including location information, network layering and in-network processing, data centricity, path redundancy, network dynamics, QoS requirements, and network heterogeneity. For each of these categories, we have discussed a few example protocols.

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