Data Communication Protocols In WSN

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***Abstract*—Recently, Wireless Sensor Network (WSN) has received increased interest of research due to its many real-life applications. This paper presents a research on the Wireless Sensor Networks of Data Communication. WSNs have identified energy efficient routing protocols as one of the energy saving mechanisms that can be used to manage the power consumption. Routing protocols help for finding paths to transmission of sensor events, and they must be able to extend the lifetime of a network.**

I. Introduction

Wireless sensor network (WSN) is recognized as one of the most important technologies of the twenty-first century. Over the past decades, it has received great attention from both academia and industry all over the world. A WSN typically consists of a large number of low-cost, low-power, and multi-functional wireless sensor nodes with sensing, wireless communication and computing capabilities. These sensor nodes communicate over a short distance through a wireless medium and cooperate to perform a common task.

In many WSN implementations, the deployment of sensor nodes is done ad hoc without careful planning and engineering. Once deployed, sensor nodes must be able to organize themselves independently in a wireless communication network. Sensor nodes are battery powered and are expected to run unattended for a relatively long time. In most cases, replacing or recharging batteries is very difficult or even impossible for sensor nodes.

II. Protocol Stack for Wireless Sensor Networks

A. *Application Layer*

The application layer contains various application layer protocols. perform various sensor network applications such as query propagation, node localization, time synchronization and network security. For example, sensor management protocol is an application layer management protocol that provides software operations to perform various tasks, for example, exchange of location-related data, synchronization of sensor nodes, sensor transport nodes, programming sensor nodes and querying the status of sensor nodes. sensor query and data propagation protocol provides interfaces to user applications to send queries, respond to queries, and collect responses.

B. *Transport Layer*

In Computer Networks, Transport Layer is a conceptual part of the methods in the layered architecture of protocols in the network stack in the Internet Protocol Suite and in the OSI model Protocols for this layer provide host-to-host communication services for applications. Provides services such as link-oriented communication, reliability, flow control and multiplexing [1]

The transport layer is the lowest layer that works end-to-end between two or more communicating hosts. A good transport layer service (or simply transport service) allows applications to use a standard set of primitives and run on various networks without worrying about different network interfaces and their reliability. [2]

The transport layer is responsible for reliable data delivery required by application layer.

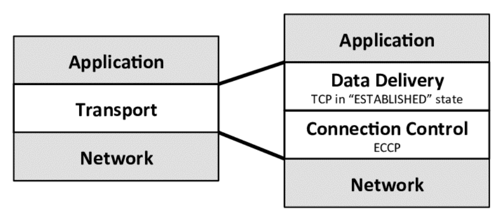

Fig. 1. The TCP / IP transport layer is divided into two sub-layers, with ECCP running below the data distribution. [3]

1) Transport Layer Protocols: The transport layer of the network protocol stack is responsible for managing end-to-end connections, for example, two well-known transport layer protocols are Transmission Control Protocol (TCP) for reliable stream-based communication and User Datagram Protocol (UDP) for unreliable packet-based communication.

Transport protocols can generally be classified into two types: link-oriented and linkless. A connectionless protocol does not need to establish a connection before data is transferred, and has only one stage: data transfer. In contrast, a link-oriented protocol has three stages for each transmission operation: connection establishment, data transmission, and disconnection. In a layered communication architecture, transport layer protocols manage data exchange between transactions on different hosts over potentially lossy communication channels. Typically, transport layer protocols are either connection oriented or based on the transmission of individual datagrams.

Well-known transport layer protocols are the connection-oriented Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP) and Stream Control Transmission Protocol (SCTP) and DCCP, the Datagram Congestion Control Protocol. [4]

- TCP (Transmission Control Protocol): TCP is reliable, connection-oriented, byte-stream protocol. Applications that require a transfer protocol to ensure reliable data delivery use TCP because it verifies that data is transmitted over the network in the correct and correct order. TCP is also responsible for transmitting data received from IP to the correct application. TCP sees the data it sends as a continuous stream of bytes, not as individual packets. Therefore, TCP takes care to preserve the order in which bytes are sent and received. [5]
  - Flow control
  - Congestion control
- UDP (User Datagram Protocol): UDP is an unreliable, connectionless datagram protocol. ”Unreliable” simply means that there is no technique in the protocol to verify that data is reaching the other end of the network correctly. UDP provides application programs with direct access to a datagram delivery service, such as the distribution service provided by IP. This allows applications to exchange messages over the network with minimal protocol overhead. UDP uses the 16-bit Source Port and Destination Port numbers in the 1st word of the message header to forward data to the correct implementation process. [5]

Data Rate	Protocol	Simulation	Average Throughput	Packet loss ratio	Connection 1	Connection 2	Fairness	Total Byte Received
1	TCP	separately	475.064 kbps	2.11724 %	2975440	2947360	28080	2975440
2	UDP	separately	949.439 kbps.	4.92472%	3116000	2808000	308000	3116000
3	TCP	interoperation	484.971 kbps.	3.81719%	3029980	3022000	7980	3029940
4	UDP	interoperation	489.707 kbps.	3.02982%	3029980	3022000	7980	3022000

Fig. 2. Comparision of TCP and UDP [6]

- SCTP: Stream Control Transmission Protocol (SCTP) is a reliable, transport-layer protocol which can be used on top of IP networks for end-to-end communications. [7]
- DCCP is a message-oriented transport layer protocol and performs unreliable data transmission. Agreements for connection setup, termination and selection of the appropriate congestion control mechanism. Similar to SCTP, most people are unaware that there is a fourth transport layer protocol that can be used with IP. DCCP is most useful when there is timing constraintsKK

C. Network Layer

1) Introduction: Wireless sensor networks (WSNs) are unique networked systems that consist of wireless sensor nodes distributed in mass. WSNs distinguish themselves from other traditional wireless networks by relying on extremely constrained resources such as energy, bandwidth, and data processing and storage. [8] The network layer is responsible for routing data detected by the source sensor nodes to the data pool(s).

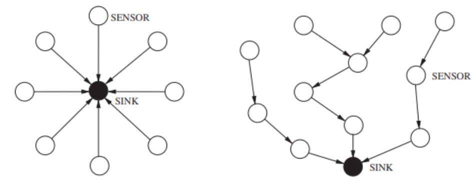

Fig. 3. Single-hop routing model (left) versus multi-hop routing model (right) [9]

Generally, a source node can transmit detected data to the sink either directly via single hop long range wireless communication or via multi-stage short range wireless communication.

2) Routing Protocols: The choice of a routing protocol for a particular network depends on the information contained in the network nodes and the tolerable communication overhead.

Centralized	Shortest (weighted) path	Interconnection networks
Distributed	Bellman-Ford	Internet
Localized - Flooding	Route discovery	Dynamic ad hoc networks
Localized - path based	Greedy, Cost/progress ratio	Sensor networks

TABLE I
COMMUNICATION OVERHEAD BASED TAXONOMY OF ROUTING PROTOCOLS. [10]

The main function of the network layer is to route packets from the source machine to the destination machine. We consider the routing task when nodes are equipped with location information. In sensor networks, the target is normally a pool whose location is passed on to all sensors before reporting.

3) Some routing protocols:

- Flat Based Protocols
  - AODV (Ad Hoc On-Demand Distance Vector) : AODV is designed for use in ad hoc mobile networks. It allows users to find and protect routes to other users on the network when such paths are needed. [11]
  - FLOODING : The Flooding Algorithm consists of sending data to all nodes in range; If a node needs to send data, it sends the data to all of its neighbors, this pattern is repeated until the information reaches its destination.
  - DSDV (Destination-Sequenced Distance Vector)
  - MTE (Minimum Transmission Energy)
  - SPIN (Sensor Protocols for Information via Negotiation)
  - Directed Diffusion
- Hierarchical Protocols
  - LEACH (Low-Energy Adaptive Clustering Hierarchy)
  - LEACH-C
  - TEEN
  - APTEEN

Protocols	**Energy Efficiency**	**Load Balancing**	**Scalability**
TEEN	high	acceptable	low
APTEEN	Moderate	Very Low	Moderate
LEACH	High	moderate	strong

TABLE II
COMPARISON OF DIFFERENT HIERARCHICAL ROUTING PROTOCOLS IN WSNS [12]

- Location-Based Protocols
  - GAF (Geographic Adaptive Fidelity)
  - GEAR (Geographic and Energy Aware Routing)
  - GPRS (Greedy Perimeter Stateless Routing)
- QoS-Based Routing Protocols

Protocol	**Characteristics**
SPIN	Flat topology, data-ccntric. query-based
Directed diffusion	Flat topology, data-ccntric. query-based
DSDV	Flat topology with proactive route discovery
AODV	Flat topology with reactive route discovery
DSR	Flat topology with reactive route discovery
LEACH	Hierarchical, support of MAC layer
GPSR	Location-based, unicast
GAF	Location-based, unicast
GEAR	Location-based, geocast

TABLE III
NETWORK LAYER PROTOCOLS SUMMARY

D. Data Link Layer

Data Link Layer must provide reliable peer-to peer communications in other words a Medium Access Control mechanism for managing distrubuted access to a shared transmission medium while minimizing power consumption and communication overhead. It is mainly devided into two sublayers: Logical Link Control and Medium Access Control. [13]

- MAC: Medium Access Control (MAC) is one of the biggest issues while designing Wireless Sensor Networks and it is one of the key network protocols that has a great impact on performance of the network. [13] Main reason for implementing MAC is to avoid collision caused by two different nodes sending data at the same time over same tranmission medium. And it tries to do this fairly, efficiently share bandwidth resources among multiple sensor nodes. [14]
  - The SMAC protocol has two phases in transceiver usage of network nodes: a sleep perion and a listen period. In sleep period nodes turn off their transceiver, after the sleep period, the nodes wake-up and listen if a communication is addressed to them or they communicate themselves. SMAC protocol requires that sleep and listen periods should be synchronized between nodes.
  - EYES MAC is a Time Division Multiple Access based protocol that divides time into time slots that nodes can use to transfet data without having to content for the medium. A node can assign only one stok to itself and should control that slot. A time slot is divided in three sections: Communication request, Traffic Control and Data section. In CR section, nodes will send requests to the node that controls current time slot at a random time. It is not guaranteed to be collision-free. Time slot controller also indicates in its Traffic Control message what communication will take place in data section. After the TC section data transfer takes place. [15]
  - LMAC (Lightweight Medium Access Control) is based on Time Division Multiple Access. Time is divided into time slots like EYES MAC. But with LMAC unlike other TDMA based systems time slots are not divided among the networking nodes by a central manager and they can be used at a non-interfering distance.

    During its time slot, a node will transmit a message with two parts: *control message* and *data unit*. A time slot can only be controlled by a single node so communication is collision-free.

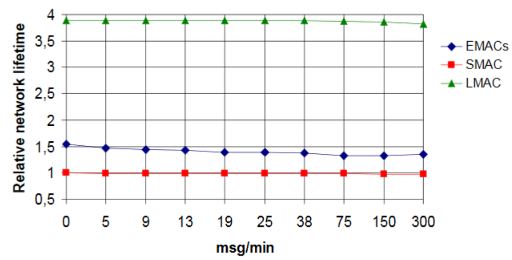

Fig. 4. Relative network lifetime comparison for EMACs, SMAC and LMAC [15]

E. Physical Layer

The task of the physical layer is to convert the bitstreams from the data link layer into signals suitable for transmission over the communication medium. It is also possible to flexibly locate nodes and nodes can be placed in areas otherwise inaccessible to wired nodes and reorganization can be done without disrupting the normal functioning structure. However, wireless communication shows some challenges like limited bandwidth, limited transmission range, and poor packet delivery performance due to noise, fading, and multipath scattering. [16] The selection of frequency is an important problem for communication between sensor nodes. One option is to use license-free radio and industrial, scientific and medical (ISM) tapes in most countries. The main advantages of using ISM bands include free usage, broad spectrum, and global availability. However, it has already been used for some communication systems such as ISM bands, wireless telephone systems and wireless local area networks (WLANs). On the other hand, sensor networks require small, low cost and ultra low power transceivers. For these reasons, the 433 - MHz ISM band and the 917 - MHz ISM band have been proposed for use in Europe and North America, respectively. In addition to radio, optical or infrared may be a possible option. [16] For example, the Smart Dust project used optical media for transmission. However, both require a sender and receiver to be in line of sight to communicate with each other, which limits their use to some extent.

1) Basic Components of the Physical Layer: The basic components of a digital communication system are: Transmitter, channel, receiver.

Because the wireless sensor nodes are placed close together in a wireless network sensor network, short range communication is on interest. The communication source represents one or more sensors and produces a message signal, an analog signal. The signal is a baseband signal with dominant frequency components close to zero. In order to be processed by the processor subsystem, the message signal must be converted into a separate signal. Conversion requires the signal to be sampled at least at the Nyquist rate; where the minimum sampling rate should be twice the bandwidth of the signal so that no information is lost. After sampling, the discrete signal is converted into a binary stream. This process called source coding. Implementing an effective source coding technique is essential. The next step is channel coding and it makes signal more resistant to noise and interference. It also allows recovering from signal corruption. Then modulation takes place. As a result of the first task set, the modulated signal must be amplified and the electrical energy converted into electromagnetic energy by the transmitter's antenna and propagated to the desired target over a wireless link. The components of the receiver block perform the reverse process to get the message signal back from electromagnetic waves. The receiving antenna induces a voltage that is ideally similar in shape, frequency, and phase with the modulated signal. Due to the various types of loss and interference, the size and shape of the signal changes and has to go through a series of amplification and filtering processes. It is then converted back into a baseband signal through the demodulation and detection process. Finally, the baseband signal goes through a channel and source decoding steps.

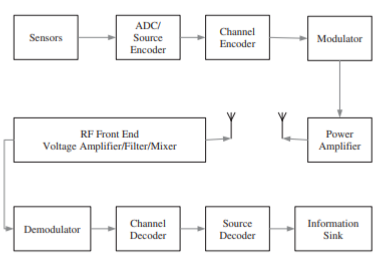

Fig. 5. Components of a digital communication system [17]

2) Modulation Efficiency: Depending on the type of modulation for each sub stream, the relative amplitude, phase, or frequency of the modulated signal carries part of the message bitstream. Modulation efficiency refers to the number of bits of information that can be transmitted in a single symbol. In a QAM with Quadrature Amplitude Modulation, the composite carrier signal contains two orthogonal signals. The amplitude and phase of these signals are varied according to the message bit stream.

Four different states of the composite carrier signal can be distinguished by the demodulator. Since the message signal is in binary form, four states can be represented by two bits. Next, the symbol rate is half the bit rate. The In an eight-state phase shift keying modulation, the phase of the composite carrier signal can have eight different states that can be mapped to eight different symbols by the demodulator.

Since eight symbols can be represented by 3 bits, the symbol rate is one third bit rate. In other words, the spectrum required by eight-state phase shift switching is one-third of the spectrum needed by a binary phase shift keying modulator. But efficiency across the spectrum is achieved at the expense of complex system design.

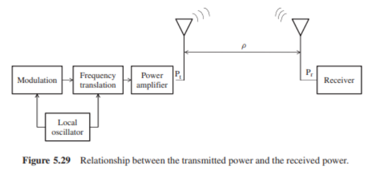

Fig. 6. [17] Relationship between the transmitter power and the received power.

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