Wireless Sensor Network Architecture

Conference Paper · April 2011

1 author:

Ahmad Alkhatib
Al-Zaytoonah University of Jordan

2012 International Conference on Computer Networks and Communication Systems(CNCS 2012)
IPCSIT vol.12 (2011)© (2011)IACSIT Press, Singapore

Wireless Sensor Network Architecture

Ahmad Abed Alhameed Alkhatib, Gurvinder Singh Baicher

University of Wales Newport,
City Campus, Usk Way, NP20 2BP, Newport, U.K.

Abstract. Wireless sensor networks are becoming very popular technology, it is very important to understand the architecture for this kind of networks before deploying it in any application. This work explores the WSN architecture according to the OSI model with some protocols in order to achieve good background on the wireless sensor networks and help readers to find a summary for ideas, protocols and problems towards an appropriate design model for WSNs.

Keywords. Wireless sensor network Architecture, wireless sensor network, WSN.

1. Sensor network architecture

Most common architecture for WSN follows the OSI Model. Basically in sensor network we need five layers: application layer, transport layer, network layer, data link layer and physical layer. Added to the five layers are the three cross layers planes as shown in Fig. 1 [1].

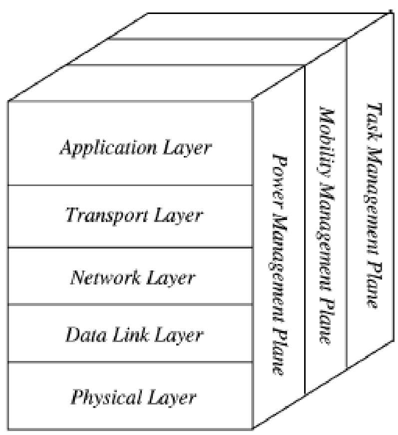

Figure 1: WSN Architecture

2. Cross layers [1, 3]

The three cross planes or layers are; power management plane, mobility management plane and task management plane. These layers are used to manage the network and make the sensors work together in order to increase the overall efficiency of the network [1].

Corresponding author. Tel.: + 447596840965
E-mail address: hamadhcumm@yahoo.com.

The difference of architectures between OSI, WLAN and WSN are shown in Table 1 [2].

Table 1: Difference of architectures between OSI, WLAN and WSN

Wireless sensor network	**WLAN**	**OSI Model**
WSN Application	Application programs	Application layer
WSN Middleware	Middleware	Presentation layer
	Socket API	Session layer
WSN Transport protocols	TCP/UDP	Transport layer
WSN routing protocols	IP	Network layer
Error control WSN MAC protocols	WLAN Adapter & device driver WLAN MAC protocols	Data link layer
Transceiver	Transceiver	Physical layer

- Mobility management plane: detect sensor nodes movement. Node can keep track of neighbours and power levels (for power balancing).
- Task management plane: schedule the sensing tasks to a given area. Determine which nodes are off and which ones are on.

2.1 WSN OSI layers

I. **Transport layer**: The function of this layer is to provide reliability and congestion avoidance where a lot of protocols designed to provide this function are either applied on the upstream (user to sink, ex: ESRT, STCP and DSTN), or downstream (sink to user, ex: PSFQ and GARUDA). These protocols use different mechanisms for loss detection ((ACK, NACK, and Sequence number)) and loss recovery ((End to End or Hop by Hop)) [4, 5]. This layer is specifically needed when a system is organised to access other networks.

Providing a reliable hop by hop is more energy efficient than end to end and that is one of the reason why TCP is not suitable for WSN. Usually the link from sink to node is considered as downstream link for multicast transmission and UDP traffic because of the limited memory and overhead avoiding. On the other hand from User to sink is considered as upstream link for mono-cast transmission and TCP or UDP traffic [1].

In general, Transport protocols can be divided into:

a) Packet driven: ‘all packets sent by source must reach destination’[4].
b) Event driven: ‘the event must be detected, but it is enough that one notification message reaches the sink’ [4].

The following are some popular protocols in this layer with brief description:

- STCP (Sensor Transmission Control Protocol) [4, 7, 8]: upstream protocol; provides reliability, congestion detection and congestion avoidance. STCP function is applied on the base station. The node sends a session initiation packet to the sink which contains information about transmission rate, required reliability, data flow. Then the sensor node waits for ACK before starting to send data. The base station estimates the arrival time of each packet, when there is a failure in packet delivery the base station checks wither the current reliability meets the required criteria. If current reliability is less than the required criteria then sink sends NACK for retransmission, otherwise do nothing. The current reliability is computed by the packet fractions that are successfully received.

- PORT (Price-Oriented Reliable Transport Protocol) [4, 7]: downstream protocol; assure that the sink receives enough information from the physical phenomena. Port adapts a bias packet routing rate to increase sink information from specific region by two methods:

    a) First method: Node price is the total number of transmissions before the first packet arrives at the sink and this is used to define the cost of communication. Each packet is sent encapsulated with source price then the sink adjusts the reporting rate according to node price.
    b) Second method: Use end-end communication cost to reduce congestion. When congestion occurs the communication cost is increased. The sink reduces the reporting rate for sources and increases the rate of other sources that have lower communication cost.

- PSFQ (pump slow fetch quick), [7, 9, 10]: downstream protocol; reliable, scalable and robust. Three functions in this protocol are; pump, fetch and report.
    a) Pump uses two timers T_{min} and T_{max}, where the node waits T_{min} before transmission, to recover missing packets and remove redundant broadcast. Node waits for T_{max} if there are any packets or multiple packets lost.
    b) Fetch operation requests a retransmission for the missing packets from neighbour.
    c) Finally report the operation to provide a feedback to the user.

II. **Network layer**: The major function of this layer is routing. This layer has a lot of challenges depending on the application but apparently, the major challenges are in the power saving, limited memory and buffers, sensor does not have a global ID and have to be self organized. This is unlike computer networks with IP address and central device for controlling [1, 11]. The basic idea of the routing protocol is to define a reliable path and redundant paths according to a certain scale called metric, which differs from protocol to protocol. There is a lot of routing protocols available for this layer, they can be divide into; flat routing (for example, direct diffusion) and hierarchal routing (for example, LEACH) or can be divided into time driven, query driven and event driven. In continuous time driven protocol, the data is sent periodically and time driven for applications that need a periodic monitoring. In event driven and query driven protocols, the sensor responds according to action or user query [3, 7].

Data aggregation and data fusion**:** In order to provide a full coverage for a certain area, even when we have a failure, we have to deploy redundant sensors. Where these redundant sensors provide a repeated data, in addition to sensors that are sending data on multi-hop style (from sensor to another till it reach the sink) and sometimes as in flood protocols, each sensor forwards data to all neighbours and the neighbours forward data to their neighbours and so on. One node can receive a huge amount of repeated data from different neighbours and this data could be generated from the same origin node or even generated by redundant nodes. Since the data processing consumes less power than data transmission, we can solve that by data aggregation and data fusion to remove the redundant data [7].
Data aggregation is described as ‘a set of automated methods combining the data that comes from many sensor nodes into a set of meaningful information and eliminate the duplication.’ This is basically used in flat routing [12].

Data fusion is described as ‘when the nodes do some more processing on the aggregated data to produce more accurate output for example reducing the noise in the signals’ [12].

Data centric routing protocols: The first data centric protocols are SPIN and directed fusion, but before that we have flooding and gossiping [12], where each node receives data, re-broadcasts it again to all nodes. This re-broadcast causes two problems; implosion i.e. duplicate messages sent to the same node, and overlap, when two nodes sensing the same region, will send the same message to the same neighbour.

Spin: broadcast ADV message to advertise for data availability, where the only interested node sends a REQ to receive the data, then the transmission starts.

Direct diffusion [12]: where the sink broadcasts a query, then certain node replies with the data by broadcasting it to the neighbours, the sink then chooses the best path and forces others to turn off, but if the current path is no longer efficient then the sink sends a negative reinforcement to reduce the rate or implement time out .

Hierarchy protocol: under this type of routing protocols there is a large number of suggested protocols for routing and considering the power consumption problem at the same time. For example, PEAS (Probing Environment and Adaptive Sleeping), GAF, SPAN, ASCENT, AFECA, CLD (Controlled Layer Protocol), MTE (Minimum Transmission Energy) , LEACH (The Low-Energy Adaptive Clustering Hierarchy). All of these protocols solve routing and energy problems by using clustering and distributing methods .

The most popular hierarchy routing protocol is LEACH [5, 12]. This divides the network into clusters and randomly selects the cluster head for it to do the routing job from cluster to the sink after carrying out data aggregation.

III. **Data link layer** [5]**:** Responsible for multiplexing data streams, data frame detection, MAC, and error control, ensure reliability of point–point or point– multipoint. Errors or unreliability comes from [13, 14]:

- Co- channel interference at the MAC layer and this problem is solved by MAC protocols.
- Multipath fading and shadowing at the physical layer and this problem is solved by forward error correction (FEC) and automatic repeat request (ARQ).

ARQ: not popular in WSN because of additional re-transmission cost and overhead. ARQ is not efficient to frame error detection so all the frame has to retransmitted if there is a single bit error [11].

FEC: decreases the number of retransmission by adding redundant data on each message so the receiver can detect and correct errors. By that we can avoid re-transmission and wait for ACK [5].

MAC layer: Responsible for Channel access policies, scheduling, buffer management and error control. In WSN we need a MAC protocol to consider energy efficiency, reliability, low access delay and high throughput as a major priorities [5]. The MAC layer is discussed in a separate paper [15].

IV. **Physical Layer** [5]: Can provide an interface to transmit a stream of bits over physical medium. Responsible for frequency selection, carrier frequency generation, signal detection, Modulation and data encryption.

IEEE 802.15.4: proposed as standard for low rate personal area and WSN with low: cost, complexity, power consumption, range of communication to maximize battery life. Use CSMA/CA, support star and peer to peer topology. There are many versions of IEEE 802.15.4.

V. **Application layer:** Responsible for traffic management and provide software for different applications that translate the data in an understandable form or send queries to obtain certain information. Sensor networks deployed in various applications in different fields, for example; military, medical, environment, agriculture fields [1, 7].

3. Conclusion

This paper conducts a survey of the wireless sensor networks architecture, the design issues, protocols and algorithm that have recently taken place to solve problems or integrated the network. The use of wireless sensor technology in any application requires a good understanding of the network architecture.

4. Acknowledgment

The authors would wish to thank the CNCS 2012 reviewers for their valuable comments and for an opportunity for updating and modifying this work.

5. References

[1] Akyildiz, I.F., Su, W., Sankarasubramaniam, y., Cyirci, E., *Wireless sensor networks: a survey*. Computer Networks, Vol. 38 no.4: p. 393-422, 2002.

[2] Mauri, K., Hännikäinen, M., Hämäläinen, T., *A survey of application distribution in wireless sensor networks*. EURASIP Journal on Wireless Communications and Networking, vol. 2005: p. 774-788, 2005

[3] Kazi , R., *A Survey on Sensor Network*. JCIT, vol.1, issue 1. 2010

[4] Pereira, P., Grielo, A., Rocha,F., Nunes, M., Casaca, C., Almsrtrom, P., Johansson, M., E*nd-To-End Reliability In Wireless Sensor Networks: Survey and Research Challenges*. in EuroFGI Workshop on IP QoS and Traffic Control, Lisbon. 2007.

[5] Koubaa, A., Alves, M., Tovar , E., *Lower Protocol Layers for Wireless Sensor Networks: A Survey*. IPP-HURRAY Technical Report, HURRAY-TR-051101. 2005

[6] Buratti, C., Dardari, D., Verdone, R., and Conti, A., *An Overview on Wireless Sensor Networks Technology and Evolution*. Sensors, vol, 9: p., 6869-6896, 2009.

[7] Yick, J., Biswanath, M., Ghosal, D., *Wireless Sensor Network Survey,* Computer Networks, vol.52, issue 12: p.2292-2330, 2008.

[8] Iyer, Y. Gandham, S., Venkatensan, S., *STCP: A Generic Transport Layer for Wireless Sensor Networks,*proceeding of IEEE ICCCN 2005, San Diego, USA.

[9] Weigle, M., *Transport Protocol in WSN,* in Virginia Technology/ Clemson workshop, 2005.

[10] Wan, C.Y., Campbell, A.T., Krishnamurthy, L., *PSFQ: a reliable transport protocol for wireless sensor network*. Dept. of Electrical Engineering. Columbia University. New York, NY, 2002.

[11] Akyildiz, I.F., Melodia, T., and. Chowdhury, K., *A survey on wireless multimedia sensor networks.* Computer Networks,vol.51, issue4: p. 921-960, 2007..

[12] Halawani, S., Khan, A., *Sensors Lifetime Enhancement Techniques in Wireless Sensor Networks - A Survey*. Journal of Computing, vol. 2, issue 5, May 2010.

[13] Bachir, A., Dohler, M., Watteyne, T., Leung, K., *MAC Essentials for Wireless Sensor Networks.* Communications Surveys & Tutorials, IEEE. Vol**.**12**,** issue 2: p. 222-248.

[14] Gunn, M., Simon, G., Koo, M., *A comparative study of medium access control protocols for wireless sensor networks*. Department of Mathematics and Computer Science, University of San Diego: San Diego, USA. p. 695-703, 2009.

[15] Alkhatib, A., Baicher, G., *MAC Layer Overview for Wireless Sensor Networks, to be published in proceeding of CNCS2012,* in Kuala Lampur, Malaysia.