Optimizing Quality of Service Evaluation in IEEE 802.15.4 Networks

T.Thirunavukarasu
Assistant Professor
Department of IT
SNS College of Technology
Coimbatore,India

A.Anitha
PG Scholar
Department of IT
SNS College of Technology
Coimbatore, India

B.Dhivya
PG Scholar
Department of IT
SNS College of Technology
Coimbatore, India

ABSTRACT

Wireless Sensor Networks (WSNs) embrace of groups of tiny sensor nodes that are deployed for shared missions such as environmental monitoring, target tracking and observation. Due to the diminutive size of the nodes, they are typically deployed in large numbers and communicate via multiple hops through a wireless shared communication channel. The successful accomplishment of such networks is dependent on the enabling technologies (such as digital electronics and wireless communications), as well as the provisioning of Quality of Service (QoS) in the network. While there have been many efforts in QoS provisioning in conventional networks such as the Internet and Mobile Ad Hoc Networks (MANETs), these networks have very different characteristics from that of WSNs. Consequently, the QoS models and protocols that have been designed for the Internet and MANETs cannot be directly applied to WSNs. The performance evaluation of quality of service parameters for WSNs based on IEEE 802.15.4 star and mesh topology. The performances have evaluated for varying traffic loads using Mobile Adhoc Network (MANET) routing protocol in QualNet 4.5. The total energy consumption is used for performance metrics.

Keywords

Quality of Service (QoS), QoS Parameters, Protocol Layers, Total energy consumption

1.INTRODUCTION

The term-QoS is used in different meanings, ranging from the user‘s perception of the service to a set of connection parameters necessary to achieve particular service quality [1]. ITU-T (Recommendation E.800 [ITU-TE.800]) and ETSI [ETSI-ETR003] basically defines Quality of Service (QoS) [2, 3] as ―the collective effect of service performance which determines the degree of satisfaction of a user of the service‖ . The goal of QoS provisioning is to achieve a more deterministic network behavior so that information carried by the network can be better delivered and network resources can be better utilized. It is becoming an important service of any communications system. Providing QoS in WSN is a challenging task due to its severe resource constraints in terms of energy, network bandwidth, memory, and CPU cycles. WSNs have also unstable radio ranges, transient connectivity and unidirectional links. So, a new set of QoS parameters, mechanisms and protocols are needed. Energy-efficiency is crucial in WSNs, which require a long network lifetime, data accuracy and the avoidance of maintenance. Moreover, certain service properties such as the delay, reliability, network lifetime, and quality of data may conflict by nature. For example, multi-path routing can improve the reliability. However, it can increase the energy consumption and delay due to duplicate transmissions. The high resolution sensor readings may also incur more energy consumptions and delays. Modeling such relationships, measuring the provided quality and providing means to control the balance is essential for QoS support in WSN [4].

2. QUALITY OF SERVICE REQUIREMENTS IN WSNs

A WSN node consists of different kinds of sensors for different unique applications. For example, it may be acceptable to lose some measurements in repeatedly transmitted environmental data, but transmitted events and one-shot queries must be reliable. In addition, critical alert messages from possibly life-threatening conditions require high reliability as well as low delay. The simplest method for providing a sufficient service is to make sure that a network has enough resources for each application. Thus, the capacity is fitted for the worst-case network usage; but this is not applicable to energy constraint WSN nodes [5].

As wired devices are AC powered and wireless devices (such as laptops) can be easily recharged, the energy is not of significant issue. In a WSN, the majority of energy consumption is caused by wireless communications, therefore requiring energy awareness. Computer networks route most of their data in a wired-backbone network, while only end nodes may be wireless (such as in wireless LANs or cellular networks).The nodes of WSN are energy constraint in resource. So, in WSN data is usually routed via multi-hop due to its low transmission range.

The wireless links of WSN nodes are prone to effects of radio interference, node mobility, changing environmental conditions or unexpected failure of a sensor node due to low energy. Even if a link has a small probability of failure, the probability accumulates on each link, which makes end-to-end communication unreliable. Due to the unreliability, the connection oriented approach like TCP used in traditional networks is impractical in WSNs. A WSN node has significant resource constraints as memory and processing power are limited. This significantly limits the available approaches for QoS. For example, storing states of each flow that passes a node is impossible. The memory constraints and the unreliability prevent using many protocols that rely on end-to-end resource reservation mechanisms [6,7].

3.CHALLENGES FOR QOS SUPPORT IN WSNs

Since WSNs have to interact with the environment, their characteristics can be expected to be very different from other conventional data networks[8]. Thus, while WSNs inherit most of the QoS challenges from general wireless networks, their particular characteristics pose unique challenges as follows

3.1Severe resource constraints

The constraints on resources involve energy, bandwidth, memory, buffer size, processing capability, and limited transmission power. Among them, energy is a primary concern since energy is severely constrained at sensor nodes and it may not be feasible to replace or recharge the battery for sensor nodes that are often expected to work in a remote or inhospitable environment. So, these constraints impose an essential requirement on any QoS support mechanisms in WSNs simplicity. Hence, computation intensive algorithms, expensive signaling protocols, or overwhelming network states maintained at sensors are not feasible.

3.2Unbalanced traffic

In most applications of WSNs, traffic mainly flows from a large number of sensor nodes to a small subset of sink nodes. QoS mechanisms should be designed for an unbalanced QoS-constrained traffic.

3.3Data redundancy

WSNs are characterized by high redundancy in the sensor data. However, while the redundancy in the data does help loosen the reliability/robustness requirement of data delivery, it unnecessarily spends much precious energy. Data fusion or data aggregation is a solution to maintain robustness while decreasing redundancy in the data, but it introduces latency and complicates QoS design in WSNs.

3.4Energy balance

To prolong the network lifetime of WSNs, energy load must be evenly distributed among all sensor nodes so that the energy at a single sensor node or a small set of sensor nodes will not be drained out quickly. So, load balancing techniques should be applied to support this feature.

3.5Scalability

A wireless sensor network usually consisting of hundreds or thousands of sensor nodes densely distributed in phenomena. Therefore, QoS support designed for WSNs should be able to scale up to a large number of sensor nodes, i. e. QoS support should not degrade quickly when the number of nodes or their density increases.

3.6Multiple traffic types

In WSN, inclusion of heterogeneous sets of sensors raises challenges for QoS support. For instance, some applications may require a diverse mixture of sensors for monitoring temperature, pressure and humidity, thereby full width of the page – one column wide. We also recommend e-mail address (Helvetica 12-point). See the top of this page for three addresses. If only one address is needed, center all address text. For two addresses, use two centered tabs, and so on. For three authors, you may have to improvise.

3.7Multiple sinks

Wireless Sensor networks may have multiple sink nodes, which impose different requirements on the network. For example, one sink may query sensor nodes located in the southwest of the sensor field to send a temperature report every one minute, while another sink node may only be interested in an exceptionally high temperature event in the northeast area. WSNs should be able to support different QoS levels associated with different sinks.

3.8Network dynamics

Network dynamics may arise from node failures, wireless link failures, node mobility, and node state transitions due to the use of power management or energy efficient schemes. Such a highly dynamic network greatly increases the complexity of QoS support.

3.9Packet criticality

The content of data or high-level description reflects the criticality of the real physical phenomena with respect to the quality of the applications. QoS mechanisms may be required to differentiate packet importance and set up a priority structure.

4. PARAMETERS DEFINING WSN IN QOS

The QoS service parameters used in traditional wired networks are throughput, reliability, delay and jitter. Security and mobility are essential in any wireless network, while data accuracy is especially relevant to the WSNs [9, 10]. The Network lifetime is usually shortened by decreasing latency or increasing any of the other parameters which affects energy consumption of WSN nodes in terms of processing, transmission and reception of data packets.

The QoS parameters for WSN are listed below as given in:

4.1 Data accuracy

A node detects a physical phenomenon within certain sensing coverage that is affected by the physical sensor and environmental obstacles. As a network may have redundant sensors and as the measurements in all areas are not equally important, energy efficiency can be improved by switching off some of the nodes. For example, the majority of the nodes in an intruder detection WSN are initially on power-save mode (sleep and low-sensing interval), while border nodes may be more active than the other nodes. When an intruder is detected, nodes are switched on for tracking movement and to determine the type of intruder.

4.2 Energy usage

As computation is often much less energy consuming than transmitting, some of the communications may be traded against computation. For example, data may be pre-processed to fit into smaller packets or by performing data aggregation. However, the aggregation has a trade-off between energy usage and reliability, as a large amount of data may be lost on a missed packet.

4.3 Reliability

In communications networks common methods for increasing reliability are using acknowledgments and error correction. Also, adding redundancy increases reliability as the network is able to recover from the loss of a single packet, but this method increases energy usage.

4.4 Latency

Latency is the time taken for the network to transfer a packet from a source node to the destination node. For critical messages, networks may need to provide delivery guarantees. As sensor networks rarely use real-time streaming applications (e.g. audio, video), the variation of the latency is less important.

4.5 Security

Security is achieved by encrypting messages and verifying that a message is authentic. However, these may require significant processing power. In addition, encryption may widen data size and authentication requires additional messaging, thus causing more communicational overheads.

4.6 Mobility

The mobility support may range from partial mobility to full mobility support. In partial mobility support, only a part of the nodes can be moved. The maximum degree of mobility may be limited to a maximum amount of mobile nodes. Also, the protocol stack and the utilized transceiver may limit mobility speed, as the communication range is limited and a node may move outside the range before having a chance to send or receive data.

4.7 Throughput

In WSN, throughput is not usually as significant as other parameters. A sensor node send typically small packets; but the use of acoustic and imaging sensors requires significant throughput, as data must be streamed through the network. Thus, certain WSN applications require maximizing throughput and possibly throughput guarantees.

5.QUALITY OF SERVICE SUPPORT IN PROTOCOL LAYERS

5.1 Application Layer

The application layer has the best knowledge regarding the importance of the data. Therefore, an application associates a generated packet with its QoS requirements. The network aims to satisfy these requirements, while minimizing the energy consumption [11]. The application layer is also responsible for making the sensor measurements and controlling sensors. There will be trade-off between the data accuracy and energy usage if an application configures sensors based on measurement accuracy versus time interval.

5.2 Transport Layer

The two main tasks for the transport layer are congestion control and reliable transmission. Typically, congestion control limits the sending of traffic to reduce bandwidth utilization. As the congestion is reduced, the overall reliability in the network is increased since the data link layer does not have to drop frames [8]. However, throughput limitations may increase delays as the source node must hold onto the generated packets that much longer. Therefore, QoS awareness is required to make a decision regarding which traffic is being more limited than the other. The energy efficiency of a transport protocol depends on the number of transmissions required to deliver a message. This is greatly affected by the acknowledgment scheme being utilized. With the positive acknowledgment scheme, the receiver acknowledges each packet. If an acknowledgment is not received within a certain time interval, the packet is resent. With the negative acknowledgment scheme, missing packets are requested by the receiver node. This reduces messaging as acknowledgments are sent only when required.

5.3 Network Layer

The network layer controls QoS with traffic shaping and routing protocol. The traffic shaping performs congestion control by classifying packets and providing queuing disciplines that provide per class QoS and fairness [11]. For example, a node may drop low-priority traffic to ensure enough resources for higher priority data. The routing protocol is responsible for selecting an end-to-end routing path fulfilling the desired QoS characteristics. As a route that maximizes one QoS metric may not be optimal on others, the route selection has to make a trade-off between different QoS metrics.

For maximizing network lifetime, a routing protocol not only tries to minimize the energy used for routing the packet, but also performs load balancing between nodes to prevent heavily loaded nodes from dying prematurely. Meanwhile, the shortest path route is not always the most energy efficient. It is due to the fact that the transmission power requirement is proportional to the square of the distance. It might be more energy efficient to forward data through two short hops than through one long hop. As longer routes usually have higher latency, the route selection therefore has to make a trade-off between energy and delay. The routing protocol design can make the selection between maintenance and routing energy consumption to determine how dynamic the protocol is.

5.4 Data Link Layer

The data link layer achieves energy efficiency by good designs of the channel access scheme. It consists of the selection between synchronized and unsynchronized data exchanges, and the usage of the low duty-cycle operation. Low duty-cycle operation has a significant impact on available QoS. While a smaller duty cycle requires less energy, it also decreases available throughput, as there are less transmission opportunities per access cycle. In addition, duty cycling also increases latency because a node must wait until the receiver wakes up before it can send a frame. Longer access cycles increase the waiting time, thus further increasing the delay. Therefore, low duty-cycle operation has a trade-off between latency, throughput, and energy usage.

The data link layer is responsible for dividing bandwidth to the traffic based on their priority and QoS requirements. The data link layer mainly controls reliability with the used retransmission scheme, but also by avoiding the collisions and hidden node problems. In addition, the adjustment of transmission power affects reliability. High transmission power enables more reliable transmission, but on the other hand, might cause additional interference within a network. The mobility support on the MAC layer is largely dependent on how often a node can communicate with its neighbors. Low duty-cycle operation and long access cycles are bad for mobility because a node might have already moved outside the communication range before it has the chance to communicate. In addition, the requirement for extensive association hand-shaking or transmission slot reservation may also limit mobility.

5.5 Physical Layer

The physical layer comprises not only the transceiver, but also Microprocessor, sensors, and the energy source. Therefore, the physical layer put limits on other layers capacity. While the transceiver causes most of the energy usage, it also imposes several other limitations to the communication protocols [11]. The data rate limits maximum achievable throughput, whereas the used coding scheme affects reliability. As the communication range is limited, the transceiver determines the minimum network density that is needed to route data. MCU puts limits to computational capabilities and available memory so as to avoid complex protocols and applications. Energy consumptions in sleep and active modes have a significant impact on energy usage.

Physical sensors have certain accuracy and acquisition time-limiting sampling intervals. To overcome these limitations, the network may need to sample data in several nodes on the same region and combine this data to get more detailed values, thus consuming more energy. Still, if a sensor supports selecting sensing accuracy, the accuracy may be purposefully reduced to make a trade-off against energy.

6.QOS ANALYSIS IN IEEE 8021.5.4 STAR TOPOLOGY

6.1 Performance Metrics

Following performance metrics are considered to evaluate the QoS in IEEE 802.15.4 networks [12, 13, 14].

Packet delivery ratio (PDR): It is the ratio of number of data packets successfully received by the PAN Coordinator to the total number of data packets sent by RFD.

Average End-to-End delay: It indicates the length of time taken for a packet to travel from the CBR (Constant Bit Rate) source to the destination. It represents the average data delay an application experiences when transmitting data.

Throughput: It is the number of bits passed through a network in one second. It is the measurement of how fast data can pass through an entity (such as a point or a network).

Energy Consumption: This is amount of energy consumed by MICAZ Mote devices during the periods of transmitting, receiving, idle and sleep. The unit of energy consumption used in the simulations is mJoule.

Energy per good put bit: It is the ratio of total energy consumed to total bits received. It is used as a figure of merit to compare the performance of various network methods based on battery powered devices

Network Lifetime: This is defined as the minimum time at which maximum numbers of sensor nodes are dead or shut down during a long run of simulations.

6.2 Simulation results discussion

Total energy consumption:

The plot for total energy consumption vs. load of three routing protocols is shown in Figure 6.1. The total energy consumption includes energy consumption in transmission, reception, idle and sleep modes of operation. It is noticed that the maximum energy dissipation occurred during idle mode while reception consumes greater energy than transmission for transferring data packets while calculating total energy consumption in our simulation. During sleep time, there is no energy consumption. The total energy consumption of three routing protocols decreases exponentially when it transferred packets from low traffic loads to high traffic loads. Routing protocols have an indirect effect on battery and energy models.

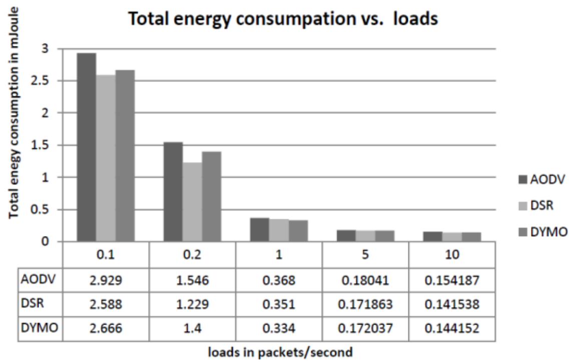


Fig.6.1 Total energy Consumption vs. loads

A routing protocol with more routing overhead would consume more energy than the routing protocol with less routing overhead. Hence, the statistics of energy and battery model could be different for different routing protocols. The DSR routing protocols performs better than AODV and DYMO at all specified traffic loads due to its low routing overhead which is clear from Figure 6.2. AODV consume more power because routing overhead in AODV is more than DSR and DYMO.

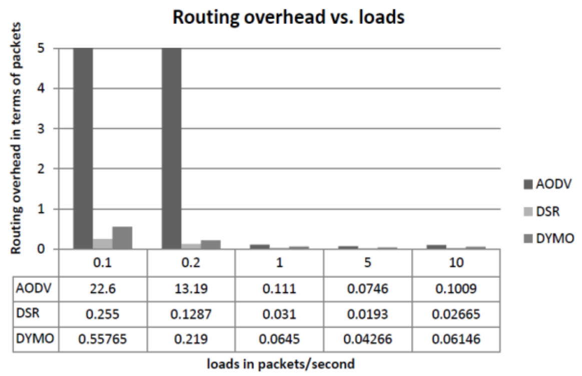


Fig.6.2 Routing overhead vs. loads

7. PERFORMANCE ANALYSIS OF QOS FOR PEER TO PEER TOPOLOGY

7.1 Performance metrics

Packet delivery ratio: It is the ratio of the number of data packets successfully delivered to the destination nodes to the total number of data packets sent by source nodes.

Average End-to-End delay: It indicates the length of time taken for a packet to travel from the CBR (Constant Bit Rate) source to the destination. It represents the average data delay an application or a user experiences when transmitting data.

Throughput: It is the number of bits passed through a network in one second. It is the measurement of how fast data can pass through an entity (such as a point or a network).

Energy Consumption: This is amount of energy consumed by MICAZ Mote devices for the periods of transmitting, receiving, idle and sleep. The unit of energy consumption used in the simulations is mJoule.

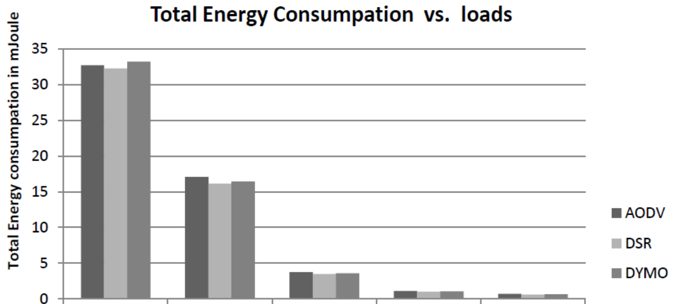
Energy per good put bit: It is the ratio of total energy consumed to total bits received. It is used as a figure of merit to compare the performance of various network methods based on battery powered devices.

Network Lifetime: This is defined as the minimum time at which maximum number of sensor nodes will be dead or shut down during a long run of simulations

7.2 Simulation results and discussion

Total energy consumption

The total energy consumption vs. load for three routing is shown in Figure 7.1 The total energy consumption is the energy consumption in transmission, reception, idle and sleep. The total energy consumption of three routing protocols decreases gradually from lower traffic loads to higher traffic loads.



	0.1	0.2	1	5	10
AODV	32.7	17.069	3.746	1.1	0.703
DSR	32.271	16.16	3.462	1	0.588
DYMO	33.25	16.44	3.6	1.05	0.662

loads in packets/second

Fig.7.1 Total energy Consumption vs. loads

8. CONCLUSION

The Wireless Sensor Networks Quality of service is significantly different from traditional wired and wireless networks. This chapter discussed the challenges for quality of service support and parameters for defining QoS in WSNs. It also discussed support and design choices of different layers like application layer, network layer, transport layer, data link layer and physical layer. To support QoS, cooperation between layers is essential. Otherwise, each layer may try to maximize different QoS metrics, which will have unpredictable and possibly undesirable results.

The QoS is more challenging in heterogeneous wireless sensors networks where a diverse mixture of sensors for monitoring temperature, pressure, and humidity are deployed to monitor the phenomena, thereby introducing different reading rates at these sensors. Here to evaluated the performance analysis of Quality of Service parameters of WSN based on IEEE 802.15.4 star (beacon enabled) mode and mesh topology (non-beacon enabled mode) topology respectively.

Simulations have been performed using reactive MANET routing like AODV, DSR and DYMO in QualNet 4.5 for varying loads**.** From the simulation results, it can be concluded that on an average DSR performs better than DYMO and AODV for different rates of traffic loads. The simulations are performed for 200 nodes and 20 applications per sessions. For mesh topology, maximum of 10 hops were considered because DSR and AODV performance is not better in comparison to DYMO when it encounters a large number of hops. If the payload size goes beyond standard IEEE 802.15.4 Max MAC Frame Size which is equal to 102 bytes, then it simply drop the packet. So, the overall performance of the three protocols on IEEE 802.15.4 for standardizing for WSNs is not promising. The major reason behind the performance degradation is all these protocols are designed mainly for mobile ad-hoc network where topology changes frequently. To meet these challenges of performance degradations, new routing protocols should be designed for IEEE 802.15.4 networks keeping in view of above routing protocols key features.

9. REFERENCES

[1] R.A.Roseline, Dr.P.Sumathi, " Energy Efficient Routing Protocols and Algorithms for WSNs-A Survey", Global Journal of Computer Science and Technology, Vol. XI, issue XXI ,Version 1,pp. 61-67, December 2011

[2] Shensheng tang Wei Li, "QoS supporting and optimal energy allocation for a cluster based wireless sensor networks", Computer Communications (ELSEVIER), pp. 2569-2577, March 2006

[3] Yannis Mazzer, Bernard Tourancheau, "Comparisons of 6LoWPAN Implementations on Wireless Sensor Networks", Third International Conference on Sensor technologies and Applications, 2009 (IEEE Computer Society)

[4] S.Misra, S.C.Misra, I.Woungang, Guide to Wireless Sensor Networks.

[5] Mario Marchese, QoS over heterogeneous networks: John &Wiley sons Limited, 2007.

[6] S. Misra, S. C. Misra, I. Woungang, Guide to Wireless Sensor Networks.: Springer, 2009.

[7] C.Perkins, E.Belding-Royer and S.Das, "Ad Hoc On-demand Distance Vector Routing (AODV)," IETF RFC 3561, July 2008.

[8] Mauri Kuorilehto, Mikko Kohvakka, Ultra Low Energy Wireless Sensor Networks in Practice Theory, Realization and Deployment. England: John-Wiley, 2007.

[9] D.B.Johnson, D.A. Maltz, Y. Hu, and J. G. Jetcheva, "The Dynamic Source routing protocol for Mobile Ad Hoc Networks (DSR)," IETF RFC 4728, February 2007.

[10] C. Buratti and R.Verdone, "A Mathematical Model for Performance Analysis of IEEE 802.15. 4 Non-Beacon Enabled mode," in European Wireless Conference , June 2009, pp. 1- 7

[11] Jose Javier Garcia, Thomas Falck, "Quality of Service for IEEE 802.15.4-based Wireless Body Sensor Networks," in Proceedings of 3rd International Conference on Pervasive Computing Technologies for Healthcare, UK,London, April 2009, pp. 1-6

[12] J.S. Lee, "Performance evaluation of IEEE 802.15.4 for low-rate wireless personal area networks," IEEE Transactions on Consumer Electronics, vol. 52, no. 3, pp. 742- 749, August 2006.

[13] Nader F. Mir, Computer and Communication Networks.: Prentice Hall, November 02, 2006.

[14] Dazhi Chen, Pramod K. Varshney, "QoS Support in Wireless Sensor Networks: A Survey," in Proceedings of the International Conference on Wir eless Networks, vol. 1,Las Vegas, Nevada, USA, 20 04, pp. 227-233

[15] Dazhi Chen, Pramod K. Varshney, "QoS Support in Wireless Sensor Networks: A Survey, "in Proceedings of the International Conference on Wireless Networks, vol. 1, Las Vegas, Nevada, USA, 2004, pp. 227-233.

[16] A.Manjeshwar and D.P. Agarwal, "TEEN : A Protocol for Enhanced Efficiency in Wireless Sensor Networks", in the Proceedings of the 1 st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile

Computing, San Francisco, CA, April 2001.

[17] B. Chen, K. Jamieson, H. Balakrishnan, and R. Morris, "Span: An energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks", Wireless Networks, vol. 8, no.5 Sept 2002.