Australian Journal of Basic and Applied Sciences, 5(8): 539-547, 2011
ISSN 1991-8178

A New Service-differentiation-based Routing Protocol for Wireless Sensor Networks

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Abstract: In many applications of wireless sensor networks, we need to guarantee quality of service parameters. Routing techniques is considered as way to support quality of service in this network. Many routing protocols had been proposed for data transfer with high-reliability and energy consumption for wireless sensor networks. Selection of optimum route is one of the main challenges due to energy efficiency and reducing the delay of sending data according to intense limitation of resources. In this paper, we introduce our new method in routing. Our new approach is based on routing to improve differentiating QoS parameters in wireless sensor networks. The proposed protocol targets WSN's applications having different types of data traffic. In the new mechanism, we use priority queues which improve total wating time for packets which are in nodes. In order to avoid congestion on nodes, we have a timing rule which drops those packets that cannot reach their destination in their deadline. Simulation results show that our new protocol can improve parameters of end-to-end delay, reliability and energy consumption.

Key words: Delay, energy consumption, quality of service, reliability, wireless sensor networks.

INTRODUCTION

Wireless sensor networks (WSNs) consist of an emergent technology deployed for a large range of solutions, spanning military, civilian, environmental and commercial applications (N. Xu, 2004; Delin, 2003). They consist of a large number of low-cost sensing devices equipped with wireless communication and computation capabilities. Given the recent advances in WSNs, it is expected that video sensors will be supported in such networks, for applications such as battlefield intelligence, security monitoring, emergency response, and environmental tracking (Bokareva, 2006; Mainwaring, 2002). For example, multimedia sensors may monitor the flow of vehicular traffic on highways and retrieve aggregate information such as average speed and number of cars (F.A. Ian, 2007). Given the physically small nature of sensors, and since multimedia applications typically produce a huge volume of data that require high transmission rates and extensive processing, power consumption becomes a fundamental concern in WSNs. More particularly, transmitting a video stream using the shortest path will drain the node of its energy along the path, thereby shortening the network lifetime, for example. Most proposals for routing in WSNs are based on a flat, homogenous architecture in which every sensor has identical physical capabilities and can interact only with its neighboring sensors (Melodia, 2006). However, flat topologies are not always best suited to handle the amount of traffic generated by multimedia applications, including audio and video (Heidemann, 2004). Therefore, developing new routing strategies to maximize the network lifetime, while satisfying the QoS requirements, represent a critical problem to be addressed. The wireless sensor network is generally used for applications such as target tracking and emergency response rather than common data. The applications have real-time requirements that sensed data must be exactly delivered to a destination node within a given time. When sensed data were received with a sink, the real time data transmission has the restriction of the time for having the validity. Even though sensed data undergoes some delay, it can have the validity with a sink and not be effective. According to a situation, it can accommodate the delay which in some cases does not exceed the threshold level. The transmission pattern of the sensor monitoring a temperature and it of the sensor for grasping the emergency situation are different. Therefore, in the wireless sensor network, it has to be satisfied the requirement having the different time restriction according to a situation in other words according to an application. Particularly, it has to satisfy not only the time restriction which has to be delivered during timeline but also the reliability which has to be accurately delivered without the loss of data in the case like an emergency or critical. The reset of paper organized as follows: in section II we explain

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the related works. Section III describes the proposed protocol with detailed. Section IV explore the simulation parameters and result analysis. Final section is containing of conclusion.

Releted Works:

Providing QoS guarantees in wireless sensor networks consists of a very challenging problem, but several approaches have been proposed in the literature for QoS support in these kinds of networks (Kemal Akkaya, 2005; Chen, 2004). A multi-path and multi-speed routing protocol called (MMSPEED) (T. He et al., 2003) takes into accounts both timeliness and reliability as QoS requirements. For timeliness, multiple QoS levels are supported by providing multiple packet delivery speed guarantees. The scheme employs localized geographic forwarding with dynamic compensation to offset inaccuracies in decisions made with only local knowledge. Intermediate nodes have the ability to boost a packet's transmission speed to higher levels if they notice that the packet may not meet its delay deadline at the current speed, although the deadline could be met at a higher speed. For reliability, multiple reliability requirements are supported by probabilistic multi-path routing with the number of paths being dependent upon the required degree of reliability. However, MMSPEED fails to consider energy issues; hence, it is only applicable for short-term WSN applications whose mission lasts only a few hours or at most one day. SPEED (Felemban, 2006) is another QoS based routing protocol that provides soft real-time end-to-end guarantees. Each sensor node maintains information about its neighbors and exploits geographic forwarding to find the paths. To ensure packet delivery within the required time limits, SPEED enables the application to compute the end-to-end delay by dividing the distance to the sink by the speed of packet delivery before making any admission decision. Furthermore, SPEED can provide congestion avoidance when the network is congested. However, while simulation results have shown that SPEED outperforms other protocols, this does not mean that SPEED is an energy efficient protocol. Because the protocols used in the head to head comparison are not energy aware protocols. The SPEED protocol does not consider any energy metric in its routing protocol, which makes a question about its energy efficiency. Therefore, for more realistic understanding of SPEED's energy consumption, it should be compared with energy aware routing protocols. RTLD (Ahmed and Fisal, 2008) protocol proposes a novel real-time routing protocol with load distribution that ensures high packet throughput with minimized packet overhead and prolongs the lifetime of WSN. The routing depends on optimal forwarding decision that takes into account of the link quality, packet delay time and the remaining power of next hop sensor nodes. RTLD consists of four functional modules that include location management, routing management, power management and neighborhood management. The location management in each sensor node calculates its location based on the distance to three pre-determined neighbor nodes. The power management determines the state of transceiver and the transmission power of the sensor node. The neighborhood management discovers a subset of forwarding candidate nodes and maintains a neighbor table of the forwarding candidate nodes. The routing management computes the optimal forwarding choice, makes forwarding decision and implements routing problem handler. Another routing protocol is DARA (Razzaque and M.M. Alam, 2008) that considers reliability, delay, and residual energy in the routing metric, and defines two kinds of packets: critical and noncritical packets. The same weighted metric is used for both types of packets, where the only difference is that a set of candidates reached with a higher transmission power is considered to route critical packets. For delay estimation, the authors use queuing theory and suggest a method that, in practice, needs huge amount of sample storages. The SAR (Sohrabi, 2000) protocol creates trees routed from one-hop neighbor of the sink by taking QoS metric, energy resource on each path and priority level of each packet into consideration. By using created trees, multiple paths from sink to sensors are formed. Furthermore, one of the paths can be selected according to the energy resources and QoS metric on each path. But the SAR approach suffers the overhead of maintaining the node states at each sensor node. Meeting QoS requirements in WSNs introduces certain overhead into routing protocols in terms of energy consumption, intensive computations, and significantly large storage (Dulman, 2003). This overhead is unavoidable for those applications that need certain delay and bandwidth requirements. In (Karp and H. Kung, 2000), the author propose a new routing protocol for WSNs that considers energy, reliability and delay for data forwarding. In this paper, we propose an improved path scheme to guarantee various QoS requirements. The proposed scheme sets up the path from sources to a sink node based on the service differentiation, and selects a route based on the sensed data characteristics. With each packet, the proposed protocol attempts to fulfill the required data-related QoS metrics.

Proposed Protocol:

In this presented method, there is not any need to keep information table of whole route from source node to destination node and just the information of neighbors are stored in node table which have one step distance to source node and they are closest to base station, so less memory is used. Source node selects the most optimized route by collecting information about energy, delay, and link quality rate and their location with creation of one cost function. In this protocol all the decisions are made based on local information, rather that information of whole network. In this section, we first explain the assumptions used in proposed protocol (SDIFR) and then describe the various constituent parts of the protocol.

Assumptions:

We assume that all nodes are randomly distributed in desired environment and each of them is assigned a unique ID. At start, the initial energy of nodes is considered equal. All nodes in the network are aware of their location (by GPS or other localization algorithm) and also are able to control their energy consumption (Karp and H. Kung, 2000; T. He, 2003). Let us assume that nodes are aware of their remaining energy and other nodes in their transmission radio range. We consider that each node can calculate its probability of packet sending with regard to link

quality. Consider a node j in the infinitesimal area OTE $dA = d\gamma d\alpha$ $dA = d\gamma d\alpha$ at coordinates (γ, α) with respect to the sink as shown in Fig 1. (Zorzi and Rao, 2003) the distance from node *j* to node *i* given by

$$d(i,j) = d(D,\gamma,\alpha) = \sqrt{\gamma^2 + D^2 - 2\gamma D cos\alpha} \quad (1)$$

Where *D* is the end-to-end distance.

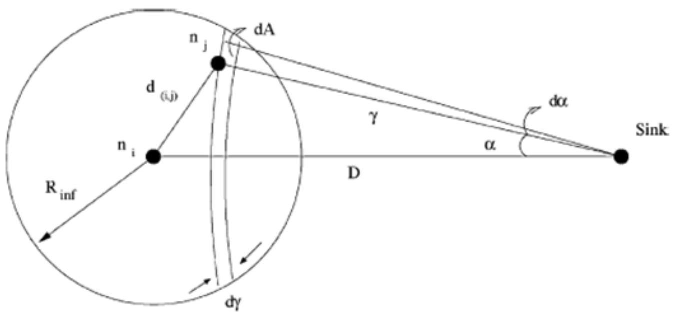


Fig. 1: Reference model for the derivations.

Building Single-hop Routing Table:

To get sufficient information for making and keeping single-hop routing table, each sensor node broadcast a HELLO message to all single-hop neighbors. Figure 2 shows the HELLO message structure.

NodeID	Residual energy	Free buffer	Link quality

Fig. 2: HELLO message structure.

The single-hop neighbor that received HELLO message, compare it with itself geographic location, and decide to response. If they were closer than sender node to the sink, they response to the message. In this protocol, we consider a threshold for node's energy. If node's energy be less than this threshold, not allowed to add to the routing neighboring table. Sender node make routing table according to arrival response packet. Energy Consumption Model.

In this approach, as shown in fig 3, energy model is obtained from (Heinzelman, 2000) that use both of the open space (energy dissipation d^2) and multi path (energy dissipation d^4) channels by taking amount the distance between the transmitter and receiver. So energy consumption for transmitting a packet of *k* bits in distance *d* is given by (2).

$$E_{Tx}(k, \quad (2)$$

In here d_o is the distance threshold value which is obtained by (3), *Eelec* is required energy for activating the electronic circuits. ε_{fs} and ε_{mp} are required energy for amplification of transmitted signals to transmit a one bit in open space and multi path models, respectively.

(3)

Energy consumption to receive a packet of *k* bits is calculated according to (4).

(4)

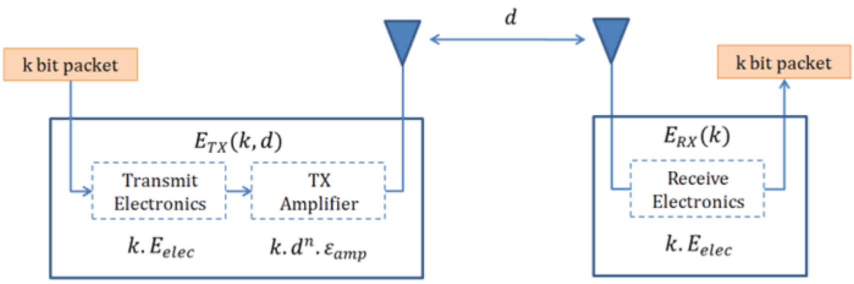


Fig. 3: Energy consumption model.

Selecting the next Node to Data Transmission:

In this section, we present a cost function to select the best single-hop neighbor node. This function considers all aspects of sending packet and selects the best candidate node among neighbors which have transmission potential. Meanwhile before finishing predefined duration for packet, we can measure waiting time of packet in priority queues. It means that there is not any need to transmit and circulate unnecessary packets in network. Cost functions are defined as follows:

$$Cost = a(UsedBuffer) + b(1/LinkQuality) + c(1/Resi \quad (5)$$

Where are weighted factors and . Link quality shows quality of connection between node and its neighbor and calculated by (6)

(6)

Where, f is packet size. By selecting the best path, we can reduce energy consumption. Finding hop count is essential to achieve end-to-end delay. There are many ways to estimate residual hop count to destination. According to lack of global information in network, we can calculate hop count with local information (Mehmet C., 2009).

(7)

Where, is the approximated transmission range, and is the expected hop distance. Each packet has one time interval to reach destination based on its type and after finishing this period, it does not have any value for destination. We can calculate Packet deadline as follows:

$$Deadli \quad (8)$$

Suppose that node forwards a packet to node *j* with delay that called .

If packet type is critical, according to its deadline and distance to sink, required speed of packet type will be calculated to timely arrival to the sink. Therefore the routing table should be searched that its speed be equal or larger than required speed. The required speed can be determined with available local information in the routing table as follow:

(9)

If search result is negative, then it sent to neighbor which has maximum speed in the table. If the neighbor node which has this speed not founded in the next hop, in order to control congestion and reduce energy consumption, packet will be removed. In the same condition for the packets, our protocol will remove the packet that has few costs for the network. For example, we don't remove the packet that had more traveled hop count and allow it to be sent to next hop that we hope to reach their destination.

Updating the Routing Table of Nodes:

When we choose a node to send packet to it, one timer is considered. After zeroing of this timer, sender node broadcast one authentication message accompanied with its current parameters to all of its neighbors, then all the neighbors which have the sender node of message in their routing table update values of related parameters. One of the most important information that be extracted from authentication message, is residual energy of node. If the energy be less than threshold energy that was considered as a default, it will be removed from all tables.

Controling Congestion and Updating Deadline of Packets:

The fundamental problem in wireless sensor networks is lack of global time between nodes. By preceding packet in network, we can update the deadline of packet. Therefore, we should make some changes in the MAC layer. So, when packets reach nodes, due to lack of global time, MAC layer put one time stamp on packet. Then received packet passes MAC layer and enters into waiting queue, then it is transmitted to sender/receiver unit and waits capturing channel and transmission through radio. Therefore elapsed time can be calculated as follows and can be subtracted from deadline packet. New deadline is given by (10)

$$Deadline_x^{new} = Deadline_x^{old} - t_{elapsed} \qquad (10)$$

And is the sum of elapsed time and given by (11)

$$t_{elapsed} = \sum_{i=1}^{h} t_i = \sum_{i=1}^{h} (t_{MAC} + t_{proc} + t_{prop} + t_{tran}) \qquad (11)$$

Where h is hop count, is delay of MAC layer, is delay of queue, is the during time of transmission. According to the new deadline, we can increases required speed of packet dynamically and consequently probability of timely arrival of packets increases and decision fault of local information decreases.

Calculating M/g/1 Queueing Dalay:

Three different classes of QoS requirements are used in the proposed protocol: 1) reliability, 2) energy efficiency, and 3) delay. The second requirement is traffic unrelated, contrary to the other ones. It can be viewed as application-related QoS metric that must be taken into account for all types of traffic, since ensuring a long network lifetime is essential for all applications. With these requirements, data traffic may be split into (Djenouri and Balasingham, 2011):

1. Normal traffic that has no specific data-related QoS need,
2. reliability-sensitive traffic, which should be delivered without loss but can tolerate reasonable delay, e.g., file transfer for long term data,
3. delay-sensitive traffic, which should be delivered within a deadline but may tolerate reasonable packet loss, e.g., video streaming, and
4. Critical traffic of high importance and requiring both high reliability and short delay (delivery within a deadline), e.g., safety alarms in vehicular applications, physiological parameters of a patient during a surgery, etc.

Following this classification, the proposed protocol is designed using a queuing model, aiming to ensure exactly the required QoS metric for each packet. To obtain low latency when routing critical and delay-sensitive packets, higher priority should be given to these packets in channel contention than the normal and reliability-sensitive packets. Also, critical packets need higher priority than delay-sensitive packets. This can be achieved through a multiqueue priority policy. We propose to use the four-level M/G/1 queues. Used data structure in this protocol shown in Fig 4 that consist of payload and header that has two bits. In our proposed protocol, the highest priority queue is used by critical packets, the second highest priority queue is used by delay-sensitive packets, and the third priority queue is used by reliability-sensitive packets, and the least priority queue is used by normal packets as shown in table I.

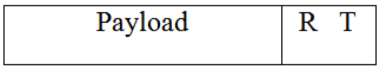


Fig. 4: Data packet structure.

Received packet is classified in the M/G/1 queue according to their priority levels. According to deadline and the number of remaining hops of reached packet, nodes are responsible for prioritization packets. On each node, there is a classifier, which checks the type of the incoming packet and sends it to the appropriate queue. There is also a scheduler, which determines the order of packets to be transmitted from the queues according to the bandwidth ratio of each type of traffic on that link. The queue model is depicted in Fig 5.

Table 1: different types of packets.

R	T	Packet type
0	0	Normal packet
0	1	Reliable-sensitive packet
1	0	Delay-sensitive packet
1	1	Critical (Delay & reliable sensitive) packet

Packets in each queue are serviced as first come first serve (FCFS). This type of classifying packets prohibits waiting of packets to send packets with lower priority. So, packets with high priority are sent to next candidate node faster and consequently the end to end delay decreases high.

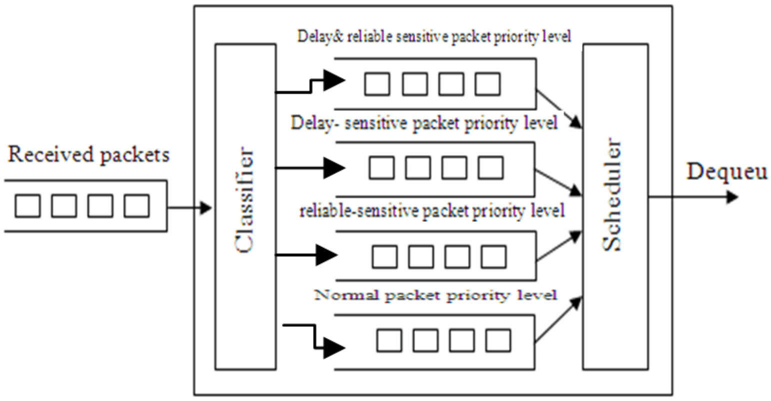


Fig. 5: Four-level M/G/1 queuing model.

Simulation and Performance Evaluation:

In this section, we present and discuss the simulation results for the performance study of SDIFR protocol. We used MATLAB simulator to implement and simulate SDIFR and compare it with the MMSPEED protocol. Simulation parameters are presented in Table II and obtained results are shown below. The radio model used in the simulation was a duplex transceiver.

Table 2: Simulation Parameters.

Parameters	Value
Band Width	200 Kbps
Terrain	100m x 100m
Packet Size	70 byte
Number of nodes	100
Node distribution	Randomly
Radio Range	20 m
Initial Energy	3.3 J
Transmission power	1 mW
Energy threshold	0.1 J
E_{elec}	50 nJ/bit
ε_{fs}	10 pJ/bit/m^2
ε_{mp}	0.0013 J/bit/m^4

We investigate the performance of the SDIFR protocol in a multi-hop network topology. We study the impact of changing the packet arrival rate on end-to-end delay, packet delivery ratio, and energy consumption.

Average End-to-end Delay:

The average end-to-end delay is the time required to transfer data successfully from source node to the destination node. Fig. 6 shows the average end to end delay for SDIFR and MMSPEED. In this evaluation, we change the packet arrival rate at the source node, and measure the delay.

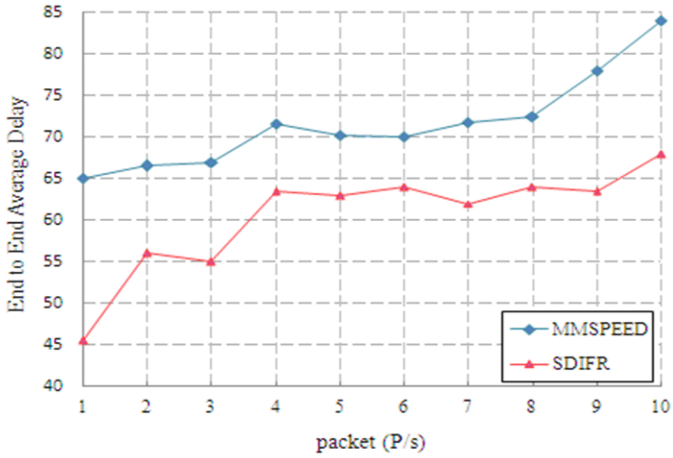
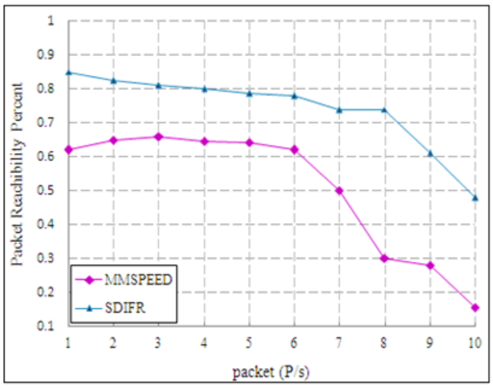


Fig. 6: Average end-to-end delay.

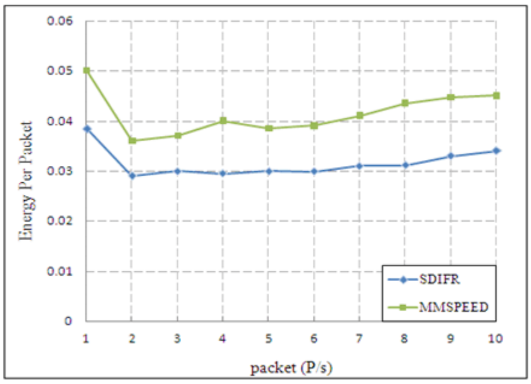
As it can be seen, proposed protocol has performance better than MMSPEED in average end to end delay. This is because that our proposed protocol uses link quality and speed rate to send packet to the next node and uses priority queue. Therefore end-to-end delay decreases.

Packet Delivery Ratio:

The average delivery ratio is the number of packets received by the destination node to the number of packets generated by the source node. In this evaluation, we set the failure ratio of some path to 5% to test the protocols behavior under the presence of path failures. Fig. 7(a) shows the average delivery ratio. Obviously, SDIFR outperforms the MMSPEED protocol. This is because our protocol uses link quality factor to select optimal path. Therefore fault ratio decreases and packet delivery ratio increases.



(a) Packet delivery ratio



(b)Energy consumption per packet

Fig. 7: (a) packets delivery ratio- (b) Energy consumption per packet.

Average Energy Consumption:

The average energy consumption is the average of the energy consumed by the nodes participating in message transfer from source node to the destination node. Fig. 7(b) shows the results for energy consumption in two protocols. As it can be seen, in our protocol, energy consumption for packet sending is much optimize in comparison to the MMSPEED. This is because that our proposed protocol uses a cost function that it selects the node which has few costs for sending packet. The MMSPEED protocol not consider constraint energy problem.

Conclusion:

In this paper, we presented a new service-differentiation-based routing protocol for wireless sensor networks. In this protocol all the decisions are made based on local information, rather that information of whole network. The proposed protocol targets WSN's applications having different types of data traffic. It is based on QoS requirements according to the data type, which enables to provide several and customized QoS metrics for each traffic category. With each packet, the protocol attempts to fulfill the required data-related QoS metrics. In the new mechanism, we used priority queues which improve total waiting time for packets which are in nodes. Therefore packets with high priority are sent to next candidate node faster and consequently the end to end delay decreases high. In order to avoid congestion on nodes, we have a timing rule which drops those packets that cannot reach their destination in their deadline. Our proposed protocol distributed packet traffic between nodes efficiently, and thus network life time is increased. The effectiveness of the protocol is validated by simulation. Simulation results show that our protocol consistently performs well with respect to QoS metrics, e.g. reliability, average end-to-end delay, and energy consumption.

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