New Combination Timeliness Routing Protocol over Wireless Sensor Networks

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Abstract: Due to new requirements of wireless sensor networks in multimedia and real-time data transmission, a new timeliness routing technique that merges ideas of the two previous famous routing protocols has been introduced in this section. THVR routing protocol which works in the network layer and tries to consider delay and energy usage as Quality of Service parameters and MMSPEED protocol which uses the layering technique to prevent greedy decisions at next hop choosing in routing, are combined and a new timeliness routing protocol has been designed to get better performance by introducing new components. A combination of the following two techniques has been used; setting layering desired speed for neighbors and choosing best next nodes. A new drop controller has been designed to handle congestion situations with better performance. All THVR, MMSPEED and the combined protocol have been simulated with prowler-msimulator. Simulation results have been compared in deadline, energy balance and energy usage as quality of service parameters and showed better performance of the new protocol in most parameters compared to THVR and MMSPEED over wireless sensor net-works.

Key words: WSN • QoS • Deadline • Energy balance

INTRODUCTION

Recent vast progress in electrical technologies led to the creation of tiny wireless sensors with improved ability to make wider sensor networks. Special conditions of wireless routing including unreliability of wireless connections and absence of infrastructure in node’s connectivity that caused self processing in nodes have been the main challenge in wireless sensor networks. The existence of tiny wireless sensors, large numbers of nodes in deployment environment, limited battery lifetime and memory, restricted bandwidth and lack of real-time human support should be added to routing challenges in WSN. TEEN [1], APTEEN [2] and SAR [3] are the first particular routing protocols in WSN that deal with less power consumption and increase of network’s lifetime using clustering techniques and head-clusters, creation of routing trees to-ward BS and utilizing GPS in detecting physical locations of nodes. Recent requirements of WSN in transmission of real-time data and video streaming led to the invention of a new category of routing protocols that specially deals with QoS parameters. In section 2, related activities are discussed. Section 3 concentrates on the design structure of the new protocol. In sections 4 and 5 simulation conditions and results in deadline, energy consumption and balance are demonstrated. Finally, in section 6, a brief conclusion is presented.

Related Works: Generally QoS-aware routing protocols are categorized in 3 sections:

- Tree based routing
- Routing based on shortest path and total information of topology.
- Geographic routing based on the physical location of nodes.

In [4] paths that have a value less than a threshold are chosen as the main paths [5]. Introduces a new AODV based protocol that uses a new parameter to decrease power consumption and increase network lifetime in addition to choosing the best path [6]. Presents a new design for WFQ mechanism in each node to afford required bandwidth for real-time and non real-time traffics. Geographic routing is a good choice for wireless sensor networks, because it does not need to maintain routing tables and decreases power consumption. Different methods are used to specify physical location of nodes. The most costless method is embedding global positioning system in some nodes and giving other nodes the ability to calculate their geographic location by means of calculating their distance with existing GPS to decrease costs. There are other techniques which provide an approximation of distance by computing propagation delay.

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Before we introduce our new design in combining the ideas of the two existing routing protocols, we should briefly explain how they work.

THVR is an extension of the SPEED protocol based on the information of the two neighbor hops. SPEED is a protocol that uses GPS to locate sensor nodes. It has a stateless architecture and tries to decrease traffic load and guaranty packet delivery without delay by applying some new routing ideas. SPEED is a soft real-time system. It has a minimum MAC support. The other attributes of SPEED are QoS routing and congestion management, void avoidance and localized behavior. Figure 1 demonstrates an overview of the SPEED protocol.

SNGF package is used to transmit data based on geographic location without maintaining the previous state. There are three definitions:

- The neighbor set of node $i$ ($NS_i$) is the set of nodes that are inside the radio range of node $i$.
- The forwarding candidate set of node $i$: a set of nodes that belong to ($NS_i$) and are closer to the destination ($FS_i$).
- Relay speed:

SNGF divides neighbor nodes belonging to $FS_i$ into two groups; nodes with relay speed larger than the defined speed parameter for meeting the quality of service needs and nodes that can not support the speed parameter. The next node for delivery is chosen from the first group and the probability to be chosen increases with greater relay speeds. There are some cases that there is no node from the first group for delivery.

In these cases another package called NFL helps SNGF. The output of NFL is $u$ that enters to SNGF. The value of $u$ is determined by the following formula:

$$ u = \begin{cases} k & \text{if } \forall q > 0 \\ u - 1 & \text{if } \exists q_i = 0 \end{cases}$$

Where:

$q_i$ is the miss ratio of neighbor $i$ inside the $FS$ collection of that node. $N$ is the size of the $FN$ set. SNGF will drop $(1 - u) \times 100$ percent of packets.

As other routing protocols use GPS, SPEED uses some control packets called "beacon" to update information about location and network control. Beacon packets are divided into two sections: the delay information beacon and the back-pressure beacon. Back-pressure beacon is used in situations that congestion exists in a zone. In these cases SPEED uses the back pressure beacon to ensure that only the packets related to the congestion zone are dropped.

[8] Proposes a two-hop neighborhood information-based routing protocol for real-time wireless sensor networks. Having more information about one-hop and two-hop neighbors helps systems to make more accurate routing decisions. In this way each node knows about its one-hop and two-hop neighbors and their physical locations. The process of locating neighbors includes sending two series of hello messages. First, each node broadcasts its information counting (ID, location, remaining energy...), then sends it's one-hop neighbors information to it's other neighbors to find out information about two-hop neighbors. One important difference between THVR and SPEED is the end to end packet delivery velocity:

$$ S_{i,j,k}^{j,k} = \frac{d(i, D) - d(k, D)}{\text{delay}_j + \text{delay}_k} $$

THVR goes further and considers energy parameters in choosing the next neighbor for packet delivery:

$$ w_{i,j,k} = C \times \frac{S_{i,j,k}^{j,k}}{\sum_{(j,k) \in S} S_{i,j,k}^{j,k}} + (1 - C) \times \frac{E_j^{j,k}}{\sum_j (E_j^{j,k})} $$

Where:

$E_j$ is the remaining energy of node $j$ as the delivery candidate and $E_j^{j,k}$ is the primitive energy. $C \in [0,1]$ And larger $C$ lead to declined end to end delay while minor leads to better energy balancing.

In THVR, among neighbors which have $w_{i,j,k} > w_{i,j,k}$ node with greatest $w$ is chosen. Like SPEED there are situations where there is no neighbor that could support requirements of QoS parameters. In these cases THVR uses a subsystem called the dropping controller.
The output of drop controller is $u_i$:

$$
u_i = \begin{cases} 
\frac{\sum_{j} e_j}{N} & d(i,D) \geq \frac{1}{2} \\
1 - K_i & d(i,d) \geq 1 \\
\frac{\sum_{j} e_j}{N} & d(S,D) \geq \frac{1}{2} \\
1 - K_i & d(S,D) \geq 1 
\end{cases}
$$

(4)

$d(i,D) \geq \frac{1}{2}$ means the packet being delivered, has traveled more than half way to it's destination, arriving at node $i$ and thus it has wasted a lot of energy for traveling from middle nodes to node $i$. So the probability of being dropped by THVR for this packet is much lower. If $K_i > K_i$ then packets that have traveled less than half of their path will be dropped with greater probability.

Simulations show that THVR has better performance in deadline miss ratio and energy per packet in comparison to SPEED. For the first time, MMSPEED focuses on satisfying the parameters of delay and reliability simultaneously. In addition, this protocol with different levels of satisfaction parameters has set a kind of differentiated service in its own way. Similar to its base protocol, MMSPEED also emphasizes on local decision making in its behavior and uses the globalization technique in order to minimize network overhead in its transparency. By having a deadline for some particular types of services and knowing the distance to the destination with assistance of GPS, we will have the following formula:

$$ReqSpeed(x) = \frac{dist_{S,D}(x)}{deadline(x)}$$

(5)

By considering the characteristics defined for several levels of acceleration and that kind of reliability differentiated service in MMSPEED we will have:

$$SetSpeed_{i,j} = \min_{j=1}^{L} \{SetSpeed \mid SetSpeed_{i,j} \geq ReqSpeed(x)\}$$

(6)

Where:

$L$ is the number of speed levels on the actual physical network, similar to the following figure:

Then, between neighbors of node $i$, the node which $SetSpeed_{i,j} = (dist_{S,D} - dist_{i,j}) \times delays_{S,i}$ is higher than $SetSpeed_{i,j}$ is selected as the next node. MMSPEED goes even further and defines different levels of reliability too.

As already explained, the main technique to maintain reliability in routing protocols is simultaneous use of multiple path routing. Considering that MMSPEED tries to perform decisions and estimations locally at each node, each node makes routing decisions locally with regard to the number of remaining hops to destination and estimates of failure.

$$RP_{i,j}^d = (1 - e_{i,j}) \times (1 - e_{i,j}) \times [dist_{i,j} / dist_{d}]$$

(7)

Where:

$[dist_{i,j} / dist_{d}]$ is the hop count estimation from node $j$ to the final destination $d$. From the end-to-end reachability estimation $RP_{i,j}$ we can determine the number of forwarding paths to satisfy the end-to-end reachability.

$$TRP = 1 - (1 - TRP) \times (1 - RP_{i,j}^d)$$

(8)

Where:

$(1-TRP)$ is the probability that none of the current paths can successfully deliver the packet to the destination and $(1-RP_{i,j}^d)$ is the probability that the one additional path via node $j$ will fail to deliver that packet to the destination. Thus, $(1-TRP)(1-RP_{i,j}^d)$ is the probability that at least one path will successfully deliver the packet to the destination.

**Design of the Combination Protocol:** The new protocol integrated multi-layer protocol by considering combinations of MMSPEED parameters and THVR routing and therefore a new combination has been created.

With regard to the speed of two hop neighbors, we had equation number 2 where $d(I,D)$ showed distance from the source to the destination node, $d(k,D)$ showed the distance from the node two hop neighbors of node $I$ ($k$) to Destination, Delay ($I,j$) was the packet delay from node $I$ to its direct neighbor ($j$) and Delay ($k,j$) showed packet delay of the two hop neighbor of node $I$ ($k$) to $I$. Thus value shows the transmission speed of
Fig. 3: Basic introduction

packets to reach the destination via two hop neighbors of node \( i \) \( (k) \). However by considering the quality of service parameters and the desired delay for the packets like what we had in 5 requested speeds will be introduced. The integrated protocol satisfies three different speed layers: low-speed, medium-speed and high-speed. This is done by the classifier as demonstrated in Fig. 4.

After recognizing the value of ReqSpeed, the protocol selection for a new value for ReqSpeed, based on speeds that are already flowing:

\[
\text{New ReqSpeed} = \min_j \left\{ \text{Speedlayer} \mid \text{Speedlayer} := \text{ReqSpeed}(x) \right\}
\]

(9)

Now that the figure of ReqSpeed has been updated, the protocol will choose the direction of routing based on the speed of its two hop neighbors:

\[
\text{Twohopneighbour is select if and only if } s_{i}^{j} \rightarrow k
\]

\[
\text{New ReqSpeed}
\]

(10)

The following diagram demonstrates the general architecture of the combination protocol and classifier subsystems:

![Diagram](image)

**Fig. 5: Combination protocol’s architecture**

**Fig. 6: Membership factor** First, a definition must be introduced:

**New DROP Controller:** In the combined protocol there are situations like THVR where none of the two hop neighbors can satisfy NewReqSpeed. Thus, according to some parameters, some packages will be dropped in order to return the network to its normal condition. First, a definition must be introduced:

**Membership factor** (F): \( d \) belongs to set \( X \) with membership factor \( = Y_{\text{new}(d)} \) (See Fig. 6)

Set \( (x) = \{ \text{low, medium, high} \} \) and \( 0 < Y_{\text{new}(d)}(\text{dist}) < 1 \).

We have:

\[
\alpha_i = 1 - \frac{\sum_{j=1}^{N} K_j}{N} \quad \text{for } i = 1, 2, 3
\]

(11)

For each set\( (x) \) based on experience, we should define a new static value of \( K_i \) and determine value of \( \alpha \). now the output of the drop controller is set:

\[
\bar{u}_i = F_{\text{low}}(\text{dist}) \times \alpha_1 + F_{\text{medium}}(\text{dist}) \times \alpha_2 + F_{\text{high}}(\text{dist}) \times \alpha_3
\]

(12)

For example in Fig. 6:

\[
F_{\text{low}}(d) = b, \ F_{\text{medium}}(d) = \alpha, \ F_{\text{high}}(d) = 0
\]

And subsequently:

\[
u_i = b \times \alpha_1 + \alpha \times \alpha_2 = b \alpha_1 + \alpha \alpha_2.
\]
Fig. 7: Energy balance comparison

Fig. 8: Deadline miss ratio comparison (different sources)

Fig. 9: Deadline miss ratio comparison (different deadlines)

Fig. 10: Energy usage comparison (different sources)
With a simple mathematical calculation it’s obvious that \(a+b+c=1\). It shows we set a variable weight instead of static ones for distance that packets have traveled. \(K_3\geq K_2\), \(K_1\geq 0\) are static values which can be determined depending on delay and initial quality of service parameters and will be totally tunable. In such cases the protocol tries to save more energy by dropping such packets with low probabilities.

As the above equation shows \(K_2\geq K_1\) causes \(ui(K_1)\geq ui(K_2)\) and subsequently drop probability will be less. And has the values of \(K_1\leq K_2\) more output will be less. \(ej\) is the packet loss ratio of node \(j\) which enters as input, into the drop controller through the Mac layer. More \(ej\) of two hop neighbors of node \(i\), less \(ui\) and finally more drop probability of packets.

**Simulation Conditions:** The proposed THVR is simulated in Prowler-rmase [8]. Prowler is a probabilistic wireless network simulator, capable of simulating wireless distributed systems, from the application to the physical communication layers. It provides simple yet realistic radio/MAC models based on the Berkeley mote platform and supports an event-driven structure similar to Tiny OS/NesC. Rmase has extended Prowler to more options of topologies, application models and routing designs. [THVR said]. In this paper it was tried to set the same condition like THVR protocol to have better and more reliable output data. MAC layer, link quality model and energy consumption parameters were set according to Mica2Motes[8]. Nodes are distributed in a 200 m × 200 m area following poisson point process with node density \(\rho = 0.0005\) node/m². The size of the neighbor table for each node is set to 400 bytes for all the tested protocols.

**SIMULATION RESULTS**

The mixed protocol is compared with THVR and MMSPEED in aspects of energy balance, energy usage of nodes for routing and end to end delay. In the following figures. In order to compare energy balance, the variance of the energy of nodes after a long duration \(K\) is used. The difference between the energy of nodes after a long duration \(K\) is calculated with in which. This is done for 6 times by changing the number of data transmission sources.

By considering the multi layer routing idea of the mixed protocol, there would be the maximum of routing in comparison with THVR and as a result the mixed protocol has shown much better performance compared to the base protocols, THVR and MMSPEED.

Next, the amount of used energy per packet for different deadlines is represented. In this case the performance of the mixed protocol is so close to the THVR protocol and much better than MMSPEED. Another parameter for comparison is the miss-rate in various deadlines and with different number of sources. The mixed protocol has the least amount of miss-rates in comparison to THVR and MMSPEED.

**CONCLUSION**

We introduce a new routing protocol at the network layer for Wireless Sensor Networks which has better performance in energy balance and performs similar to THVR at deadline miss ratio and energy consumption per packet. This new combined protocol is suitable for
networks that energy balance is a necessity and deadline of packets as QoS parameters is in average level of importance.

REFERENCES


