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Full Length Research Paper

Caching data approach in randomized re-routing algorithm (CRRR) in wireless sensor networks

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In wireless environments, congestion and link error can cause packets to be lost. These two factors are reducing the end-to-end reliability and energy efficiency. These problems can be overcome by recovering lost packets using retransmission. Since the delay is high in the end-to-end retransmissions, we are looking for a way to reduce this delay. Hop-by-hop transmission and buffering packet in some special intermediate nodes, where they can be retransmitted for another time can be a solution. In this paper, loss recovery mechanism with lost packets of data storage is proposed by using the RRR algorithm in wireless sensor networks (CRRR).

Key words: Wireless sensor network, randomized re-routing algorithm.

INTRODUCTION

A wireless sensor network consists of large tiny nodes which are distributed over a certain area. Limitation in processing power, memory and power supply are some of the factors which should be considered in building a WSN. Wireless Sensor Networks are used in some applications such as military, health, industry, etc. One of the main tasks of WSN is to offer powerful services with high reliability for a long time, while the other one is the effective and immediate sending of important data by distributed sensors (Akyildiz et al., 2002; Al-Karaki and Kamal, 2004; Chen and Varshney, 2004). Two types of data are usually used in WSN named: routine data and special events. Special events occur unexpectedly in sensor networks and information about these events need better QOS, move faster, more secure and less delays and possible higher bandwidth on the path towards the sink. The number of routine data is very high compared with the special events that rarely occur in wireless sensor networks (Gelenbe and Ngai, 2008; Gelenbe et al., 2008). Wireless sensor networks must transmit special events from deferent sensors to one or more sinks (Pomer and Mattern, 2004). Since the delay is high in end-to-end retransmissions, hop-by-hop forwarding is used in this paper. With these conditions, RRR algorithm can send data from a particular direction to enhance reliability and ensure that the special events will send it back to the sink even if the packets that are lost occurred in a way chosen by the RRR algorithm, using caching method. In this paper, a new method for data storage mechanism with the path chosen by algorithm RRR (CRRR) is proposed.

RANDOMIZED RE-ROUTING (RRR) ALGORITHM

Randomized re-routing is an adaptive algorithm that is able to detect the occurrence of special events and the ability to create better and faster QOS for special events packets. In this algorithm, nodes can change their routing policies based on the network traffic, in a way that if traffic is less than a threshold, both routine and special data will transmit from a preferred route; otherwise, special events will be sent from the preferred route and the routine data will be transmitted from the other routes which are selected randomly (Gelenbe and Ngai, 2008).

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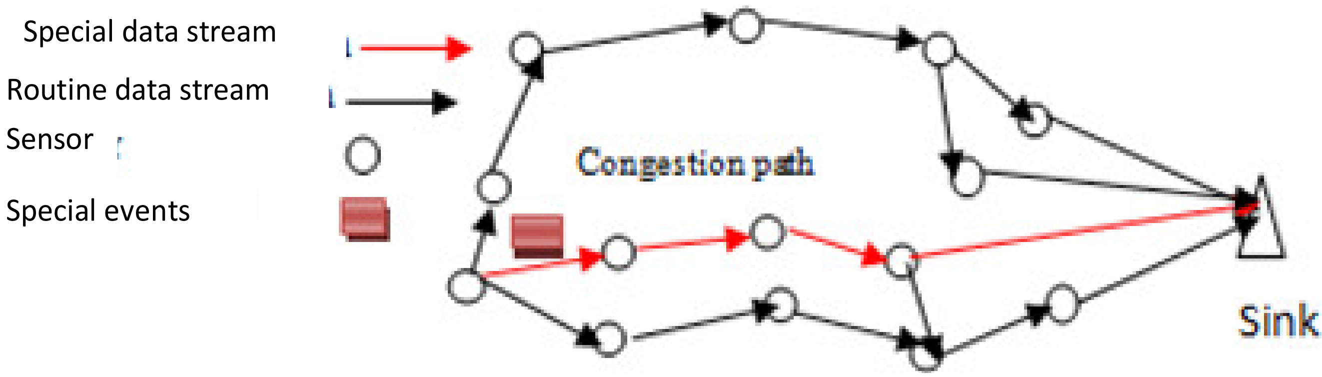

Figure 1. Congestion created by special events.

Algorithm 1 Detecting the occurrence of unusual events

For Each time interval T **do**

Each node monitors the current sensor measurement m(t)

Updates $M(t) = a \cdot m(t) + (1-a) \cdot M(t-T)$

If $|M(t) - M(t-T)| \leq \varepsilon$ **then**

Marks packets as ZERO – bit

Else

Marks packets as ONE – bit

Figure 2. Detection algorithm for the occurrence of unusual events.

Sensor network congestion with special events

Nodes in wireless sensor networks send data to the sink at any time and it always try to choose the best route for both special events and routine data. This will cause congestion on the path mentioned, in that this has little impact on regular packets but it is a very critical issue for packets with special events and reduced network performance. Figure 1 shows congestion created by special events (Gelenbe and Ngai, 2008).

Detection of the occurrence of special events

Detecting the occurrence means the packet will be detected as special events or packet routine data. If the current received packet is different from the previous received packet in the same source, then the packet will be detected as a special packet, otherwise the data packet will be detected as routine data. RRR algorithm differentiates the received packet by putting zero-bit in the packet header for routine data and one-bit for special events. Figure 2 shows the proposed detection algorithm for the occurrence of special events (Gelenbe and Ngai, 2008).

In this algorithm, M (t) represents the running average, T indicates the short time window and m (t) is the indicator value of measurement.

Each node i monitors the number of received special events packets. If this number is not more than the threshold, both the routine and special packet data will be transmitted from the preferred route, in which this route has better QOS, else each node will be grading their neighbor nodes based on their distance to the sink (i_1 ... .. i_H). i_1 represents the nearest neighbor nodes to the sink and i_H is the farthest sink node. The node sends packets with header one-bit to the neighbor's i_1..... i_k and header packets with zero-bits to the remaining neighbors i_{k+1} ... .. i_H. Figure 3 shows the proposed routing algorithm based on the traffic level in the network (Gelenbe and Ngai, 2008).

Caching data

Due to the low range of nodes, hop-by-hop approach is better in wireless networks. Reducing the delay and ensuring that the sending packets will certainly be received in the destination node are the issues of discussion in WSN. Storage data packets at some intermediate nodes can be an appropriate solution. For this case, transmission would be done via hop-by-hop approach, based on a

Algorithm 2 Routing for differentiated quality of service

For each time interval T do
  Each node monitors the incoming packet rate T_t
  If $T_t < \theta_U$ **then**
    Forwards packets to the neighbor on the preferred path
  Else
    Ranks the best H neighbors in nlist to $i_1,\ldots,i_H$
    If ONE –bit packets **then**
      Forwards packets to neighbors $i_1,\ldots,i_k$
    Else
      Forwards packets to neighbors $i_{k+1},\ldots,i_H$

Figure 3. Routing algorithm based on the trafic level in the network.

Algorithm 3 Transmit

$P_{tx}(i) \leftarrow P_{tx}(i-1).(1-P_i)$
If $P_{tx}(i)>CR$
  Then $F(i) \leftarrow$ false
  Else $F(i) \leftarrow$ true
    $P_{tx}(i) \leftarrow (1-P_i)$
    Cache data packets to a node n_i

Figure 4. Transmit algorithm for storage data packet.

parameter used as communication reliability (CR). There are two fundamental problems in storing the intermediate nodes, which include:

(1) Sending packet P_{tx} (H) that H is the total hops which must be greater than the CR.
(2) Packet transmission rate P_{tx} (h) in hop h must be larger than the CR data.

Each node can solve the second problem by using tables P_{tx} (i) and F (i). As such, P_{tx} (i-1) and F (i-1) will be stored in the packet and sent to the next node. In the sender node, P_{tx} (1) = 1-P_1 and F (1) will be true. Figure 4 shows the proposed transmit algorithm used for storing data packet (Kim and Cho, 2009).

P_{tx}(i) calculated in each node from Equation (1) (Kim and Cho, 2009) is the sender node and h represents the number of hops:

$$P_{tx}(s,h) = \prod_{i=s}^{s\ h-1} (1-P_i) \quad (1)$$

Also P_i is used for Equation (2) (Kim and Cho, 2009) as follows:

$$P_i=P+\alpha i^2 \quad (2)$$

where α is the failure factor and p is a communication error.

The achieved P_{tx}(i) when compared with CR, do not cache data in the node if P_{tx} is larger than the storage, else the node is selected to perform the storage operation (Kim an Cho, 2009). Figure 5 shows the proposed operation data storage algorithm for each node (Kim and Cho, 2009).

In the algorithm in Figure 5, N_c represents the number of caching nodes, in which the action taken storage Φ is coupled with the stored number of node in the data packet.

Retransmission count is obtained for h hop from a node is saved

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Algorithm 4
n←1, s←1 , h←1 , Nc←0
ϕ = Φ
loop: n < N
      If Ptx(s,h)>CR
            then n←n+1 , h←h+1 //no caching
            Else h←h-1              //caching
                  If (h=0)
                     then h←1 , n←n+1
                  add (s,h) to ϕ, Nc←Nc+1
                   s←n , h←1
End loop
If (h>1)
     then add (s,h-1) to ϕ, Nc←Nc+1
```

Figure 5. Operate data storage algorithm.

by Ψ(s, h). The total number of retransmissions is shown by the total Ψ (s, h) between the source nodes and sink node:

$$E[C] = \sum_{j=1}^{N_c} \Psi(s_j,h_j) \quad (3)$$

In Equation (3) (Kim and Cho, 2009), Ψ(s, h) is obtained by $\Pi_f(j, s, h)$ which refer to the number of retransmission packets (Kim and Cho, 2009).

$$\Psi(s,h) = \sum_{j=1}^{\infty} (h. \prod{}_f(j,s,h) .P_{tx}(s,h) \quad (4)$$

THE STUDY'S PROPOSED RRR ALGORITHM IMPLEMENTATION WITH CACHING DATA (CRRR)

It was explained earlier that Randomizes re-routing is an adaptive algorithm that has the ability to detect the occurrence of special events and create a better QOS for packets. In this algorithm, nodes can change their routing policies based on network traffic conditions. The study's proposed approach implementation is done in five steps: Route discovery process, neighbor table update, set priority packets, route selection based on packet priority and data storage in chosen route. In the route discovery phase, each node broadcasts the route discovery message to all its neighbors, including the address of parents' nodes and the minimum number of hops to the sink. Subsequently, each node that receives the message will be compared with this hop count. If the new hop count is smaller, then the nodes with parents will change their beacon sender and update the hop count. In the neighbor tables' update phase, each node keeps its neighbors table based on the hop counts in its implementation. Each node, by beacon messages, updates its neighbor's tables in a round-robin process with an increasing order (Gelenbe et al., 2008). In the set priority packets phase, the received packet type is identified by Algorithm 1. Thus, the packet will be detected in the special events; otherwise the typical packet would contain the routine data. If the current received packet is different from the previous packet received at the same source, the packet will be detected as a special packet. This algorithm adds the zero-bit and one-bit to the header packet. In the route selection phase, each node i reached the number of packets containing the observer special events. If this value is not more than the threshold, the routine that contains both types of data packet will be transmitted to the preferred routine and the path with better QOS, otherwise routing will be done in algorithm 2. In this paper, the randomized re-routing algorithm was improved, so the fifth step that is called the data storage phase was added to it. This storage phase was mentioned previously, and due to the existing insecure communication, high probability of special packets lost occurred. In this case, when data caching happened, P_{tx} is smaller than CR so the nodes can have CR (Communication Reliability) given storage special packets. Thus, we propose loss recovery mechanism with data storage by using the RRR algorithm, which is called caching data approach with randomized re-routing algorithm (CRRR) in wireless sensor networks. For this purpose, the CRRR mechanism has been used to prevent loss special packets with saving data methods. In this paper, we focus on the reliability and QOS in wireless sensor networks. Thus, this method increases the reliability of the chosen route. However, the CRRR mechanism increases the reliability, has better QOS and reduces

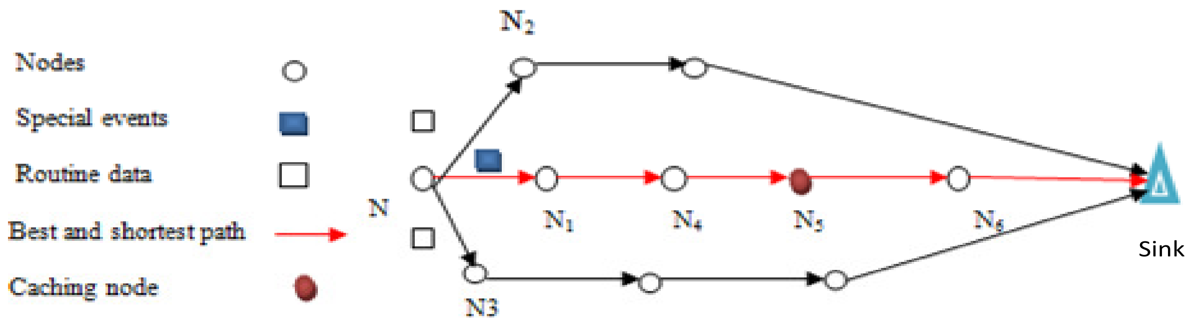

Figure 6. Caching data with randomized re-routing algorithm.

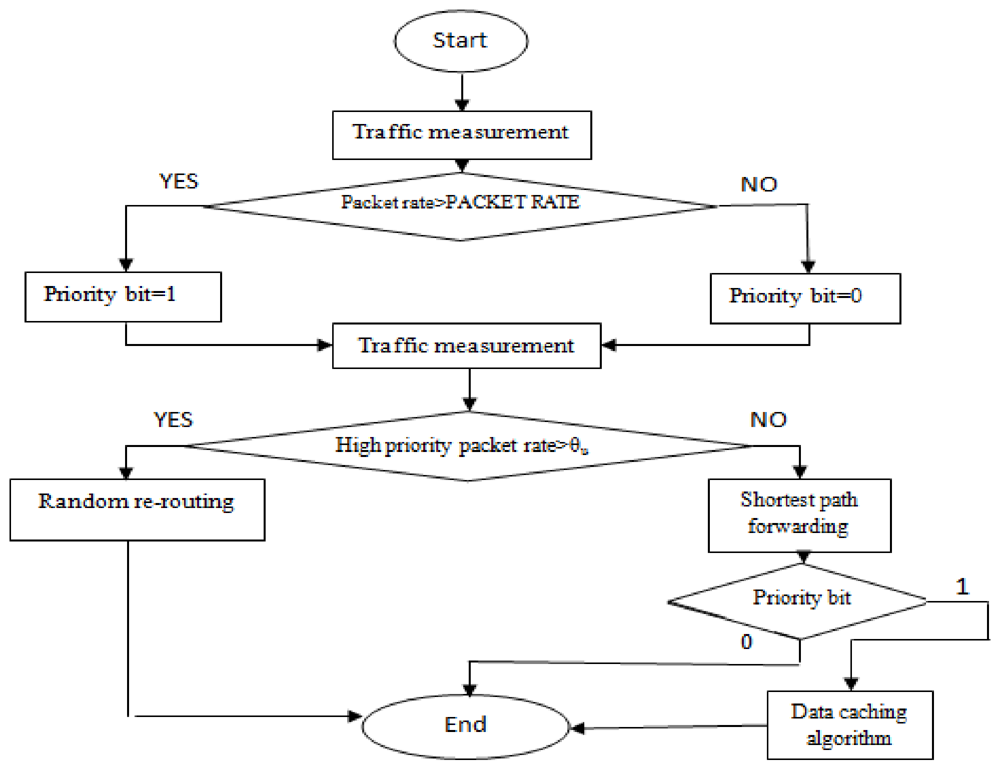

Figure 7. Our proposed mechanism algorithm flowchart (CRRR).

delay in sending special packets to the sink.

Figure 6 shows how the CRRR mechanism operates. Node N has three neighbors, N_1, N_2 and N_3, which are ordered according to their distances to the sink. In this example, the first node N selects their neighbors according to their distance. When N receives a one-bit packet, it transmits it to its neighbors which have the least distance to the destination, while it transmits zero-bit packets to N_2 and N_3 that have the greatest distance to the destination. So the shortest route is selected to the sink that has better QOS. Thus, node N sends special events from this route and routine packets transmit them from the secondary paths. However, for data storage in this path, value $P_{tx}(t)$ is calculated according to Algorithm 3 and Equation (1), having CR in each route. This value is compared with CR and the nodes are calculated with the caching operation. In this example, it is assumed that caching operation is done in node N_5. So, if one of the special packets is lost, the sink can request retransmission of node N_5 instead of node N. Thus, it is seen that the mechanism used in this study increases the reliability and reduces delay in sending special packets to the sink.

Figure 7 shows the flowchart of the study's proposed mechanism. This flowchart shows the common route discovery with caching data for all nodes in wireless

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Algorithm 5
Each node monitors the packet rate
  If packet rate>PACKET RATE
    Priority bit=1
   Else
    Priority=0
      If High priority packet>θU
        Forwards all higher priority packets on the preferred
      Else
        Nodes will route all the packets along the shortest paths to sink
           If priority bit=1 then
             While Ptx(s,h)>CR
               F(i)←false                    // no caching
               F(i)←true                     // caching
               Ptx(1)←(1-P1)
               Cache data packet to a node
           Else
               Forwards packets on the other paths
```

Figure 8. CRRR algorithm.

sensor networks.

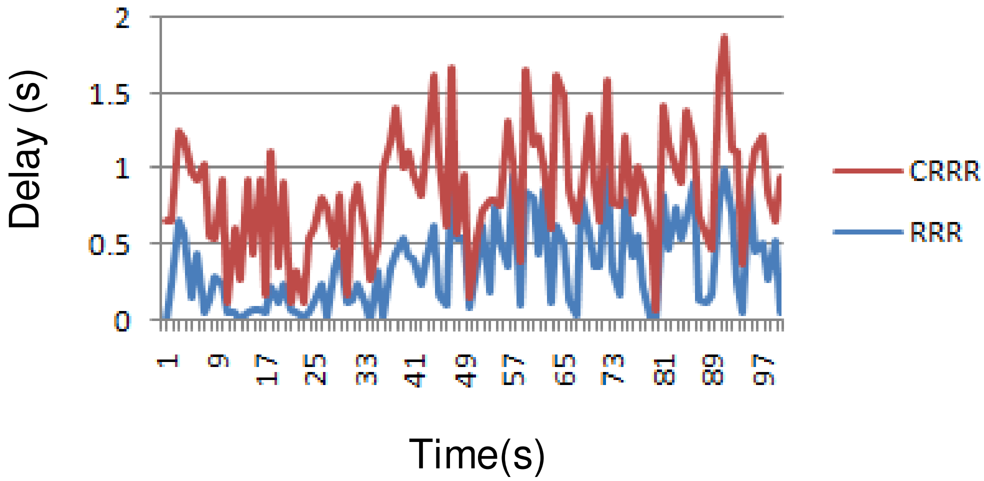
Figure 8 shows the study's proposed algorithm for loss recovery with lost packets of data storage using the RRR algorithm in wireless sensor networks.

Simulation

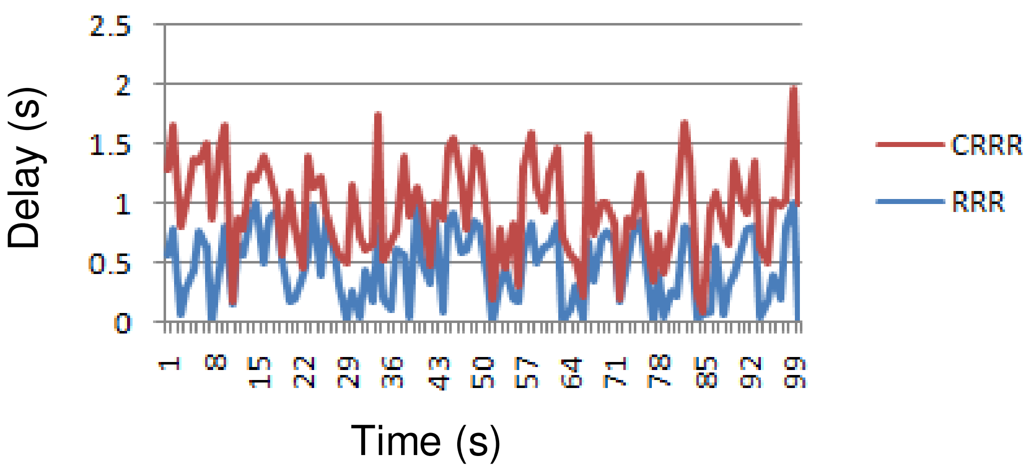
Extensive simulations have been performed to evaluate the performance of the study's scheme. The simulation parameters are described as follows: 100 sensors are randomly deployed in 100×100 m^2 sensor field. The transmission range of the sensors is 30 m and the sink is located at the center of the square. The maximum communication channel bit rate is 32 kbps. In this study, it is assumed that each packet size is 30 bytes. The number of special event sources is 4 and is located at (50, 50), (50, 150), (150, 50) and (150,150), whereas routine data sources probability is p = 0.1, failure rate is f = 0 and f = 0.1, time-out constant is 1/r, delay for retransmission (M) is 0.02s, data rate of special events is $\lambda_U = 5$ pkt/s (Figure 9) and data rate of routine data is $\lambda_R =$ 1 pkt/s(Figure 9).

CONCLUSIONS

In this paper, a new method of data storage mechanism was proposed with the path chosen by algorithm RRR (CRRR). This new mechanism has the ability to detect the occurrence of special events. In this algorithm, the nodes can change their routing policies based on the traffic network. This approach selects the shortest path that has better QOS. If traffic is more in the preferred route, only special packets are sent from the route selected and other packets are sent from the sub-paths. This makes the sending operation of the packets to be faster than the sink. Since special events are needed for the packets to get to the sink, the method of caching data was used, so that if the packets are lost, they will be retransmitted. Thus, this method increases the reliability of the chosen route. Nonetheless, the CRRR mechanism increases the reliability, has better QOS and reduces delay in sending special packets to the sink.



(a)



(b)

Figure 9. Travel delay vs.p with f=0,λu=5 pkt/s, λ_R= 1 pkt/s.(a) with delay =0, (b)with delay =0.1.

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