Poster: Fast and Reliable Burst Data Transmission for Backscatter Communications

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Abstract

Computational RFID sensors are able to transfer potentially large amounts of data to the reader in the RF range. In this paper, we propose a method for burst data transmission by fragmenting large data packets into blocks. We introduce a burst transmission mechanism for burst transmission when there are critical and emergency data to be transmitted. In addition, we utilize erasure codes to reduce ACK delay and improve system robustness. Simulation results show that our proposed scheme significantly outperforms current approach and is close to the theoretically optimal value.

1 Introduction

Due to the potential for permanent sensing without batteries, CRFID sensor systems have received increasing attention in recent years[3]. CRFIDs are widely used in industrial production, clinical monitoring, environmental monitoring and other fields to achieve tracking, positioning and early warning.

With the widespread deployment of CRFIDs, sensing tasks are becoming more complex and the sensing data is increasing. In particular, when it need to be transmitted quickly and efficiently for critical and emergency data, current backscatter communication brings some challenges. First, commercial RFID systems follow the EPC C1G2 protocol, which is designed to read a small amount of data (identifier EPC) for a large number of tags, but is less efficient in scenarios where CRFIDs need to transfer large amounts of buffered data. Second, existing passive sensing systems cannot adapt to dynamic changes in both energy harvesting and channel conditions. Third, due to insufficient energy and changing channel conditions, the transmission data is incorrect, resulting in data retransmission and large delays.

In response to the above difficulties, following are the chief contributions of our work.

- We propose a method for burst data transmission by fragmenting large data packets into blocks. Then we dynamically adjust the frame length of every block through an online adjustment strategy at runtime by the feedback of the reader.
- We introduce a burst transmission mechanism. The core idea is to let a tag occupy all time slots for burst transmission when there are critical and emergency data to be transmitted, which reduces the idle time slot.
- We utilize erasure codes to reduce acknowledgement frame waiting delay and avoid retransmission overhead, which improves system robustness and reliability.

2 Design Preliminary

Sleep time The energy harvesting rate is a concave function of the sleep time[4]. By continuously tracking the maximum harvest point,we can obtain the optimal sleep time t_o and energy harvesting rate. A fast and efficient way to converge to the optimal value of the concave function is used by the gradient descent algorithm. Then calculate the RF energy captured by the CRFID node and further derive the optimal number of transmission frames n_k under the current condition.

Erasure codes The node encodes N source data frames that be required to transmit into $N+M$ frames through the XOR of several random source data frames[1], where M is the number of redundant frames. Each frame is sent only once, and the reader can decode and restore the original data by successfully receiving any frames. Thus, there is no need to acknowledge each frame for the reader, which reduces ACK delay. If the number of errors in the data frame is greater than $M+1$, it means the data restoration failed.

3 Method design

We propose a method for burst data transmission by fragmenting large data packets into blocks. Then we introduce a burst transmission mechanism that is to let a tag occupy all time slots for burst transmission when there are critical and emergency data to be transmitted. In addition, in order to deal with the error of data frames, we introduce erasure codes to improve system robustness and reduce ACK delay. The main idea of our solution is to adjust the frame length and coding redundancy according to the goodput feedback of the reader at runtime.

Frame length of every block When a round of data

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Algorithm 1: The CRFID operation procedure

while the buffer id not empty **do**
  if receive Query or QueryRep command **then**
    return RN16
  end
  if receive the ACK containing the same RN16 **then**
    extract N data frames of length l_p and encode into $N+M$ (l_p and M are carried in the ACK)
  end
  repeat
    track the capacitance voltage and obtain $U_{\max}$ and τ and sleep for a period of t_o
    compute the optimal number of transmission frames n_k then transmit them to the reader
  until all $N+M$ frames have been transmitted
end

Algorithm 2: The reader operation procedure

Initialize l_p =16bits, $M=M_{\min}$, V =0, R =0, F =0
send the Query or QueryRep command
if receive the RN16 from CRFID **then**
  return an ACK with the same RN16 and l_p and M
end
if receive the frame from CRFID
  if the frame is correct **then**
    $V=V+l_p$; $R=R+1$
  else $F=F+1$
  end
  if $R=N$ or $F=M+1$ **then**
    compute $G=V/\Delta t$,where Δt is the transmission time of the current round
    if $G>G'(1+\theta)$ and $l_p<l_p^{\max}$ **then**
      $l_p=l_p+8$
    else if $G<G'(1+\theta)$ and $l_p>l_p^{\min}$ **then**
      $l_p=l_p-8$
    end
  end
compute the number of redundant frames M via the formula for the next round
end

transmission is completed, the reader obtains the time spent and goodput, and compares the current round goodput with the previous round. If the current round goodput is higher than the previous round goodput, the ACK is returned to inform the CRFID node to increase the length of the transmitted frame l_p; otherwise, the frame length l_p is reduced, and the unit of increasing or decreasing the frame length is 8 bits.

Coding redundancy After one round of transmission, the reader counts the number of redundant frames M actually transmitted in the case of successful transmission of the current round. If the transmission of the current round fails, the number of redundant frames in the next round is updated according to formula:

$$M_{\text{next}} = \lceil 1-\alpha \times M_{\text{avg}} + \alpha \times M_{\text{cur}} + M_{\min} \rceil$$
$$\alpha \in (0,1), M_{\text{next}} \in (M_{\min}, M_{\max})$$

Pseudo codes of the CRFID and the reader operation procedure are shown in Algorithm 1 and Algorithm 2, respectively.

4 Performance evaluation

We use the USRP N210 software defined radios and WISP as backscatter nodes for our instantiation of our scheme. Our goal in the evaluation is to demonstrate that our proposed scheme can significantly improve system goodput by simulations.

To model the changing energy harvesting and channel conditions, we evaluate the performance with different values of E_b/N_0 and different combinations of $U_{\max}$ and τ. E_b/N_0 is the signal-to-noise ratio (SNR) per bit.

In order to verify the effectiveness of our proposed scheme, we compare our proposed scheme with the EPC C1G2 protocol fixed frame length approach and DFCA scheme[2] and theoretical optimal values. Simulation results show that our proposed scheme achieves 19.8x more goodput than current fixed frame length approach, and 9.2x more goodput than DFCA scheme, and the goodput close to the theoretically optimal value under different energy harvesting and channel conditions. The delay is reduced by 30% than EPC Gen2.

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