저전력광역 네트워크에서의 버스티 트래픽 수용을 위한 전송제어 알고리즘

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Transmission Control to Accommodate Bursty Traffic in LPWANs

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요 약

In this paper, we propose an improved online adaptive backoff algorithm with the bursty factor, which can auxiliary adjust the backlog size to accommodate the bursty traffic. We first have a judgment on whether the current traffic situation is bursty or not, then we update the estimated backlog size base on the judgment. The numerical result shows that the improvement of the bursty factor yield quite a similar backlog size to the ideal one and can relieve the congestion caused by the bursty traffic.

Ⅰ. 서 론

THE INTERNET OF THINGS (IoTs) [1] would change our lives. Sensing devices collect data to make better reactive decisions for efficiency according to their applications [2]. In smart agriculture, wireless sensor networks required that the sensor nodes that are used once can achieve a wide range of wireless connectivity with very low power consumption and be used for a long time. Low Power Wide Area Network (LPWAN) remote (LoRa) technology [3] has been proposed to facilitate the application of IoT in a large coverage area. Unslotted ALOHA protocol has been adopted as a channel access mechanism in commercial low-power wide area networks (LPWANs), such as long-range (LoRa) alliance. The online adaptive algorithm [4] can track the backlog size of the system with time-varying and static arrival rates, but it cannot perform well when it comes to bursty traffic, a large number of end-devices trying to access the gateway at the same time. We further optimize to track reasonably the backlog size of the system with time-varying when devices come to bursty traffic.

Ⅱ. 본론

Suppose N end-devices are randomly scattered under the coverage area of one serving gateway. We assume the end-devices are activated at time x∈(0, T_A) whose probability density function (PDF) is the Beta distribution with parameters α = 3 and β = 4:

$$f_X(x) = \frac{x^{\alpha-1}(T_A - x)^{\beta-1}}{T_A^{\alpha+\beta-1}B(\alpha,\beta)} \tag{1}$$

When an end-device has a packet to send, we call it backlogged. We consider an exponential random backoff (ERB) algorithm for the backlogged end-devices to perform, upon retransmission, end-devices with ERB algorithm draw an exponential random variable with mean 1/(β)(s).

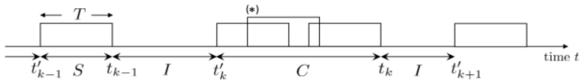


Fig. 1. Timing diagram of the unslotted ALOHA system.

As shown in Fig. 1, the online adaptive algorithm uses the idle period I between t_{k-1} and t'_{k-1} to estimate the backlogged end-devices at t'_k, we use Xt'_k to denote the backlogged end-devices value in t'_k. Since the gateway broadcasts a backoff rate β at the end of t_k, the gateway also takes into account how many end-devices would join during the period of success or collision at time t_k in Fig. 1. However, this algorithm cannot work well when it comes to a bursty traffic scenario, so we improve the algorithm by adding bursty factor, which denotes by $\Delta\alpha$ in Algorithm 1.

To be specific, suppose that the system has Xt'_k backlogged end-devices and the number of backlogged end-devices is a Poisson process with mean α . We have

$$Pr[X=m] = \frac{\alpha^m}{m!}e^{-\alpha} \tag{2}$$

Then we set the bursty factor for the proposed system. When it comes to a bursty traffic scenario, the difference of backlogged end-devices number between epoch t_{k-1} and t_{k-2} should be larger than the difference between epoch t_{k-2} and t_{k-3}. Therefore, we set the slope of the previous means by $\Delta\alpha_1$ and $\Delta\alpha_2$ in line 6 and line 7. If the value of $\Delta\alpha_1$ is greater than $\Delta\alpha_2$ and are positive value, we see the current system traffic as bursty traffic. Then we let $\Delta\alpha_1$ be a correcting offset of the previous mean α_{k-1} and get $\alpha_{k-1} = \alpha_{k-1} + \Delta\alpha_1$ so that α_{k-1} could reflect the bursty increase in newly backlogged end-devices.

Algorithm 1 Improved Online Adaptive Backoff Algorithm

```
1: Initialize α, λ, at epoch k = 0
2: if either success or collision begins then
3:   I = t'_k − t_{k−1}
4:   λ_k = θλ_k + (1 − θ) (1/(t_k − t_{k−1})) 𝕀(S)
5:   if k > 3 then
6:     Δα_1 = α_{k−1} − α_{k−2}
7:     Δα_2 = α_{k−2} − α_{k−3}
8:     Δλ = λ_k − λ_{k−1}
9:     if Δα_1 > Δα_2 > 0 then
10:      α_{k−1} = α_{k−1} + Δα_1
11:      if Δλ > 0
12:        λ_k = λ_k + Δλ
13:      end if
14:    end if
15:  end if
16:  if success then
17:    α_k = α_{k−1} e^{−β* I} + λ_k · T_S
18:  else
19:    α_k = 1 + α_{k−1} e^{−β* I} + λ_k · T_C
20:  end if
21: end if
22: Broadcast β* = 1/(2α_k) at t_k
```

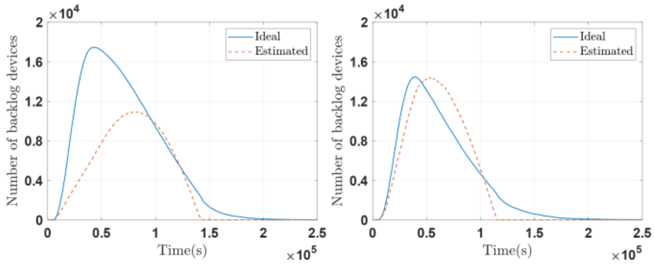
Moreover, the estimated packet arrival rate λ also require a compensation factor correcting the offset. We set the slope of the previous means $\Delta\lambda$ in line 8. If the value of $\Delta\lambda$ is a positive value, we let $\Delta\lambda$ be a correcting offset and get $\lambda_k = \lambda_k + \Delta\lambda$ so that λ_k could accurately estimate packet arrival rate in the bursty traffic.

The update equations in lines 17 and 19 are related to estimating $E[Xt_k^{-} \mid I = t]$ based on observation I in line 3. The estimation of backlogged end-devices number can be expressed as

$$E[X|I=t] = \frac{E[X, I=t]}{f_I(t)} = 1 + \alpha e^{-\beta t} \qquad (3)$$

By applying (3) with I, upon success we subtract one from it as line 17; that is, one end-device leaf the backlogged end-devices. Since the number of end-devices newly joining the backlog is $\lambda_k \cdot T$ during the period of success, the new arrivals during the collision period are added $\lambda_k \cdot C$. Finally, $\beta*$ is broadcast as in line 22.

We assume that the random access slots are equal to $T = 1$(sec). Extensive computer simulations:



(a) Online adaptive algorithm. (b) Online adaptive algorithm with bursty factor.

Fig. 2. Number of backlogged end-devices over time when $N = 20000$ and $\alpha = 3$, $\beta = 4$.

Fig. 2(b)shows the estimation made by the improved algorithm keeps track of the actual value quite well, which demonstrates our improved algorithm performs better than the original online adaptive algorithm.

Fig. 3 shows the total service time over end-device number N between the original algorithm and the improved algorithm. Total service time is the time taken for all packets to be sent to completion. We can see the algorithm with bursty factor consumes less total service time than the original algorithm. That means our bursty factor can relieve the congestion caused by the bursty traffic.

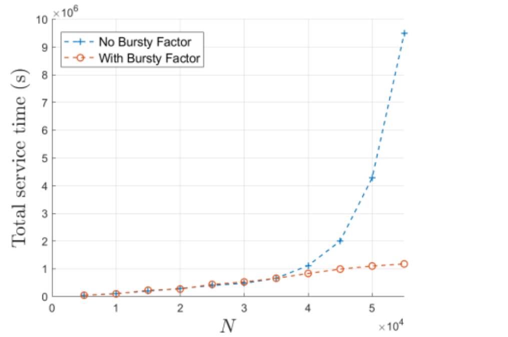


Fig. 3 Total service time over end-device number N

Ⅲ. 결론

In this paper, we consider an improved online adaptive backoff algorithm to track the backlog size of the system with time-varying in the bursty traffic environment. Numerical results show that the proposed improved algorithm can track the backlog size well and relieve the congestion caused by the burst traffic.

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