Appendix

Proof 10: Suppose that EDF policy can finish all packets in Π_2 but the k-th packet $p_k^{\Pi_1}$ in Π_1 violates its deadline at time slot D_k at link e. Let $t_{\text{last}} \leq D_k - C$ be the last time slot that the packet $p_k^{\Pi_1}$ is waiting for transmission at a link no later than $D_k - C$. Without loss of generality, at time slot t_{last}, we assume that the packet $p_k^{\Pi_1}$ is waiting for transmission at the link e. For all the packets that traverse the link e, we classify them into two categories:

C1: All the packets that deadline is before or at time D_k;

C2: All the packets that deadline is after time D_k.

Let $t_0 = \max\{t \leq t_{\text{last}} : \text{no C1-packet is pending at the link } e \text{ at time slot } t\}$ be the last time slot before D_k such that the link e has no pending C1-packet. Since the C1-packet $p_k^{\Pi_1}$ is at the link e at time slot t_{last}, we must have $t_0 < t_{\text{last}}$. Consider the time slots from $t_0 + 1$ to $t_{\text{last}} + 1$, the link e must be busy serving C1-packets. These C1-packets arrive at the link e at or after time slot t_0, and have a deadline no later than D_k. We use Ω to denote the set of all such packets. It's easy to verify that every packet $p_k^{\Pi_1} \in \Omega$ satisfies the conditions in Lemma 2. Hence, the packet $p_k^{\Pi_1} \in \Omega$ must arrive at its source link at or after time slot $t_0 - \Delta(p_k^{\Pi_1}, e)$. Consider the same packet $p_k^{\Pi_2}$ in system Π_2. Its arrival time must satisfy $A_k^{\Pi_2} \geq A_k^{\Pi_1} \geq t_0 - \Delta(p_k^{\Pi_1}, e) = t_0 - \Delta(p_k^{\Pi_2}, e)$. Note that the time required to transmit $p_k^{\Pi_2}$ from its source to the link e is at least $\Delta(p_k^{\Pi_2}, e)$. The arrival time of $p_k^{\Pi_2} \in \Omega$ at link e must be at least t_0.

Besides, the deadlines of all the packets in Ω are no later than D_k and all the packets can meet their deadlines in Π_2. $\Delta(p_k^{\Pi_2}, e, e_{\text{final}})$ is the minimum number of time slots required from link e to the destination e_{final}. Thus, the total number of packets in Ω must be no larger than $D_k - \Delta(p_k^{\Pi_2}, e, e_{\text{final}}) - t_0$.

Now consider the system Π_1. If $t_{\text{last}} - t_0 \geq D_k - \Delta(p_k^{\Pi_2}, e, e_{\text{final}}) - t_0$, we must be able to transmit $p_k^{\Pi_1}$ at time t_{last}. Otherwise, we have $t_{\text{last}} < D_k - \Delta(p_k^{\Pi_2}, e)$. If $e = e_{\text{final}}$, $\Delta(p_k^{\Pi_2}, e, e_{\text{final}}) = C$, then $t_{\text{last}} < D_k - C$, which contradicts the assumption that $t_{\text{last}} \geq D_k - C$. If $e \neq e_{\text{final}}$, $\Delta(p_k^{\Pi_2}, e, e_{\text{final}}) \leq C - 1$, hence there exists t' that $t_{last} < t' \leq D_k - C$. It contradicts the assumption that t_{last} is the last time slot that the packet $p_k^{\Pi_1}$ waiting for transmission.