OPTIMIZATION OF ARQ ALLOCATION FOR ULTRA-RELIABLE AND LOW-LATENCY COMMUNICATION IN MULTI-HOP NETWORKS

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by

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Dedicated

to

My Beloved

Parents and Sister -

who always inspire me to dream big!

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Certificate

This is to certify that the thesis entitled **"Optimization of ARQ Allocation for Ultra-Reliable and Low-Latency Communication in Multi-Hop Networks"**, submitted by **Jaya (aka Jaya Goel)** to the Bharti School of Telecommunication Technology and Management, Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** has been carried out under my supervision. The work contained in this thesis have not been submitted either in part or in full to any other university or institute for the award of any degree.

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Abstract

Multi-hop networks comprising Line-of-Sight (LOS) dominated wireless channels have found attractive applications in wireless networks, such as in vehicular networks involving unmanned aerial vehicles. These applications are known to demand both high-reliability and low-latency features on communication links. While Automatic-Repeat-Requests (ARQs) or Hybrid-ARQs (HARQ) based decode-and-forward (DF) relaying strategies provide the high-reliability feature, they are known to incur delays owing to multiple re-transmissions of packets. To address the trade-off between the reliability and the low-latency features of ARQ-based or HARQ-based DF strategies, in this thesis , we impose a sum constraint on the total number of ARQs across the nodes as it captures an upper bound on end-to-end delay for packet transmissions. Subsequently, we solve the problem of optimally distributing the total number of ARQs across the nodes such that the end-to-end packet drop probability (PDP) is minimized under various non-cooperative, semi-cumulative, cluster-based, and fully-cumulative strategies. For each of the proposed strategies, we provide a set of necessary and sufficient conditions on the optimal ARQ distribution and use these conditions to synthesize low-complexity algorithms to obtain near-optimal solutions. In addition to the PDP metric, we also analyze the packet delay profiles to compare the latency of all the strategies and show that the packets reach the destination within the deadline with an overwhelming probability.

सार

मल्टी-हॉप नेटवर्क जिसमें लाइन-ऑफ-साइट (एलओएस) प्रमुख वायरलेस चैनल शामिल हैं, ने तार रहित नेटवर्क में आकर्षक अनुप्रयोग पाया है, जैसे मानव रहित हवाई वाहनों से जुड़े वाहन नेटवर्क में। ये अनुप्रयोग संचार लिंक पर उच्च-विश्वसनीयता और निम्न-विलंबता दोनों सुविधाओं की मांग करने के लिए जाने जाते हैं। जबकि स्वचालित-दोहराव-अनुरोध (एआरक्यू) या हाइब्रिड-एआरक्यू (एचएआरक्यू) आधारित डिकोड-एंड-फॉरवर्ड (डीएफ) रिलेइंग रणनीतियां उच्च-विश्वसनीयता सुविधा प्रदान करती हैं, उन्हें पैकेटों के एकाधिक पुन: प्रसारण के कारण देरी करने के लिए जाना जाता है। एआरक्यू-आधारित या एचएआरक्यू-आधारित डीएफ रणनीतियों की विश्वसनीयता और कम-विलंबता सुविधाओं के बीच व्यापार-बंद को संबोधित करने के लिए, इस थीसिस में, हम नोड्स में एआरक्यू की कुल संख्या पर एक बाधा डालते हैं क्योंकि यह एक ऊपरी सीमा को पकड़ता है। पैकेट प्रसारण के लिए एंड-टू-एंड देरी पर। इसके बाद, हम नोड्स में एआरक्यू की कुल संख्या को इष्टतम रूप से वितरित करने की समस्या को हल करते हैं जैसे कि एंड-टू-एंड पैकेट ड्रॉप प्रायिकता (पीडीपी) को विभिन्न गैर-सहकारी, अर्ध-संचयी, क्लस्टर-आधारित और पूरी तरह से कम किया जाता है। संचयी रणनीतियाँ। प्रस्तावित रणनीतियों में से प्रत्येक के लिए, हम इष्टतम एआरक्यू वितरण पर आवश्यक और पर्याप्त शर्तों का एक सेट प्रदान करते हैं और निकट-इष्टतम समाधान प्राप्त करने के लिए कम-जटिलता एल्गोरिदम को संश्लेषित करने के लिए इन शर्तों का उपयोग करते हैं। पीडीपी मीट्रिक के अलावा, हम सभी रणनीतियों की विलंबता की तुलना करने के लिए पैकेट विलंब प्रोफाइल का भी विश्लेषण करते हैं और दिखाते हैं कि पैकेट अत्यधिक संभावना के साथ समय सीमा के भीतर गंतव्य तक पहुंच जाते हैं।

Contents

List of Figures

List of Tables