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論文の内容の要旨

With the growing demands of wireless applications and mobile data connections, wireless communication is expected to provide the ever-increasing demand for higher data rate and efficient data communication. Energy consumption is also one of the main problems for the mobile wireless devices because they all depend on the limited battery power installed inside them. Recently, network coding has been introduced as an enabling technology to fulfil the highest achievable capacity of multicast transmissions in butterfly-topology networks. It is also said that network coding has a special advantage to the wireless networks with no extra cost due to the broadcast nature of wireless transmission. This dissertation investigates the potential benefits of network coding to provide efficient data communication for multihop wireless communication and to fulfil the requirements of future wireless networks.

The targeted problems are approached from the viewpoint of multihop communication and the proposed solutions involve the application of network coding techniques. Network coding has a high potential to be incorporated on the Internet in future due to its advantages such as reduction in the number of transmissions and providing high reliability and robustness. However, more work is still needed to realize the practical application of it. This dissertation considers the application of network coding in different scenarios to achieve the efficient data communication.

In this dissertation, an efficient network coding based data transfer framework is proposed, which utilises network coding (NC) to assist data transmission, data collection and data sharing among the wireless nodes to be more efficient in terms of high throughput, low latency, fairness and low energy consumption. Three schemes comprise in the framework for the three scenarios which have high potential to become popular soon. For the first scenario, a network coding-aware medium access control (necoMAC) scheme is developed, which is a combination of network coding-aware 2-hop path selection protocol (NCA-2PSP) and network coding-aware carrier sense multiple access (NCA-CSMA) protocols for the higher rate data transmission from

one node to another. These MAC protocols exploit the multi-rate capability of IEEE 802.11 PHY and golden topologies such as chain and triangle inside the network as key resources for network coded transmissions. These protocols introduce a relay control message, which informs the sender to use a higher rate for transmitting the data frames.

The second scenario includes data gathering applications in a wireless sensor network (WSN), hundreds of nodes are spatially distributed to collect information about the physical environment. Their energy is consumed not only for sensing but also for networking functions to propagate the sensed data to a remote device, base station (BS). The most obvious challenge of a WSN is energy efficiency. Ultra-low latency and ultra-high reliability are also needed for the real-time data collection from the physical environment. For this scenario, an energy-efficient network coding based data gathering scheme called necoDG is proposed. Random linear network coding (RLNC) is applied to the aggregator or cluster head (CH) node to support the reliable data communication from CH to BS. A network coding-aware medium access control protocol is incorporated into cluster-based WSN for the data transmission from each sensor node to the CH node.

For the problem of mobile data downloading from a base station (BS), a balanced cooperative network coded transmission scheme called BCCT is proposed to achieve fast downloading satisfaction. This work includes data sharing within a group of wireless devices by exploiting the two interfaces, cellular and Wi-Fi, which are present in a standard mobile phone. The BCCT scheme applies linear network coding and transmission of the combined data frames to the devices located in the one-hop distance. An algorithm for selecting the next transmitter and choosing the better combination is introduced to maintain fairness among members of the group. The purpose is to satisfy their required data frames as quickly as possible with the fewer number of transmissions.

The proposed schemes are evaluated by computer-based simulation in multihop wireless network environments in terms of the performance metrics such as throughput, energy consumption, latency, fairness and overhead ratio. The results show that the overall performance is improved by 30% compared to conventional methods. The necoDG scheme obtains about 15.2% energy saving on average. The BCCT scheme significantly balances the number of transmissions made from each device and reduces 8.92% of the total number of required transmissions.

Keywords: Network coding, Efficient data communication, Multihop wireless communication, MAC protocol, Cooperative data exchange

論文審査の結果の要旨

The Evaluation Committee recognizes that the research work presented in the dissertation is the data transfer of data link layer in the exploration of network coding technique for providing an efficient data transmission, data gathering and data sharing in the multihop wireless networks. An Efficient Network

Coding (E-neco) Data Transfer framework that comprises of a network coding-aware medium access control (necoMAC) scheme, an energy-efficient network coding based data gathering (necoDG) scheme, and a balanced cooperative network coded transmission (BCCT) scheme is designed and proposed in the dissertation. The E-neco Data Transfer framework exploits the golden topologies (e.g., chain, triangle, cross, butterfly, and so on) and utilizes the group formation for clustering and grouping the best combination of data gathering and data sharing, respectively. The E-neco Data Transfer framework also exploits the data link layer network coding, including XOR, RLNC, and PLNC. The E-neco Data Transfer framework has reached a very good competence with clear vision and objectives of research works in multihop wireless networks. The proposed three schemes of E-neco Data Transfer framework are well-examined by comparing to the state-of-the-art other schemes and their comprehensive results and discussions are clear-demonstrated. The Evaluation Committee identifies that the dissertation contains the appropriateness of the given literature backgrounds, the wide-ranging related research works, and the research methodologies for the numerical evaluation studies. Besides that, the numerical results are validated and extensively well-discussed to justify the correctness, efficiency and effectiveness of the proposed schemes. The dissertation also includes clear and specific conclusions, contributions and recommendations for future works. In addition, the references are appropriately presented in the dissertation.

The Evaluation Committee validates and confirms that the research works in each chapter of the dissertation have been disseminated to the three international conferences, two accepted journals and one submitted journal. The Evaluation Committee agrees that Nyan Lin did make very good achievements and momentous contributions to the data transfer of multihop wireless networks, in particular the wireless network coding technique. Furthermore, this research work is a frontier step toward the wireless network coding technique for the future wireless networks. The Evaluation Committee observes that he speaks frequently in English and his ability in oral presentation is excellent. Hereby, the Evaluation Committee concludes that he with no doubts deserves to obtain the doctoral degree (Information Science).