Faculty of Engineering and Technology

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ENEE5304

INFORMATION AND CODING THEORY

Network Coding

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Introduction

In terms of the world of modern communication techniques, a modern transformative concept called Network Coding reshaped the operation of data transmission throughout the network. Network Coding is a relatively recent subset of network information theory that has led to great advancements in the optimization of network throughput. In this report, the definition of Network Coding will be investigated. The impact of this concept on wireless networks, its benefits, in terms of both the improvements it has made and its resulting application to various categories within wireless networking. In addition, the challenges that appeared to this technique will be discussed.

Theoretical Background

- ### *Network Coding Definition*

Network Coding refers to the process that encodes the transmitted data and decodes it on arrival at its destination. The traditional existing routing algorithm generally caches the arrival packets and data and foreword it using the concept of first-in, first-out (FIFO), in other words, using the queuing approach. So when the network receives two packets from different sources, it forwards them one-by-one and queued even if both of them have the same destination.

So, the concept of Network Coding is used and developed to make the network perform and works faster and efficiently by merging the messages that have the same destination or receipt to be forwarded simultaneously, and these messages will be separated in the decoding process.

There are **three main Schemes** of Network Coding: **Random Linear Network Coding (RLNC), Triangular Network Coding, and Opportunistic Network Coding.**

- ### *Benefits of Network Coding*

Throughput: One of the most important advantages of network coding is increased throughput, as one message is sent to the same recipient instead of five separate messages, which reduces the number of times that the network encrypts data before it is encrypted. This helps reduce the chances of network congestion.

Guaranteed Robustness: Network coding helps avoid losing the packet while it is being sent, as the reason for this loss can be bypassing the buffer, interruption of the link, or collision, and this loss leads to damage to the data sent through the wireless network. By setting up an acknowledgment system, this setting aims to know if the message that was sent has reached the sender or not. If the message arrives, the recipient acknowledges receiving it. If the recipient does not receive the message, the sender will be notified. This method allows the sender to send the unsent message again.

Enhanced Security: Through network coding, which encrypts data packets before they are sent, this ensures that only recipients can decrypt this data and read its contents.

Automated Scalability: Through network coding, the network can automatically adapt to the size of the messages sent through its ability to combine messages intended for the same recipient, which allows the network to expand better.

Improved Network Resilience: Network coding has a data backup and recovery feature, which can ensure that no data is damaged or lost during transmission. Thus, there is no interruption between communications [1].

- *Applications and Where We Use It*

Network Coding is considered to be very useful and important part of the network where the same data needs to be transmitted to a number of destination nodes. Some of these applications are mentioned in the following:

Video, audio streaming, and conferencing: The performance of MPEG-4 traffics in terms of packet loss or delay over wireless networks that are prone to packet erasure can be improved by using **RLNC** in the case of streaming audio over wireless networks, and the delivery rate and latency of packets and network jitter performance can be greatly increased when using RLNC instead of protocol-based forwarding of packets.

VOIP (voice over internet protocol): The performance of broadcast services such as audio transmitted over wireless networks can be improved by network coding and by reducing network delays.

Software-defined wide-area networks: Network coding improves the performance of SD/WAN networks with a large number of nodes and multiple cellular connections.

Wireless Mesh Networks (WMNs): Which consists of multiple routers and clients (users) forming a multi-hop network. Applying Network coding will help to improve the efficiency gains, and the number of transitions while exchanging the data will be reduced.

- *Challenges that Network Coding Solved*

Network coding emerges as a solution to several challenges encountered in wireless networks. Firstly, it tackles the dynamic and unpredictable nature of wireless links, marked by varying link quality and interference levels, it addresses the need for improved throughput in wireless networks. Thirdly, Network Coding leverages the broadcast nature of wireless communication to enhance reliability. In contrast to wired networks, where a single designated next-hop is prone to failure, wireless networks benefit from multiple potential nodes that can receive and forward packets, bolstering reliability. Lastly, network coding capitalizes on spatial diversity, allowing multiple nodes to receive the same broadcast packet. This spatial diversity can be harnessed to optimize network performance, improving data delivery.

While network coding offers solutions to these challenges, it also introduces its own set of challenges and limitations in wireless networks. Firstly, integrating network coding into the existing network stack of wireless devices and infrastructure is a complex endeavor, requiring substantial modifications across different layers of the protocol stack. Secondly, the computational

overhead associated with network coding operations may strain the resources of resource-constrained wireless devices, potentially affecting their energy efficiency.

Thirdly, effectively managing interference caused by concurrent transmissions and ensuring proper synchronization of nodes during coding operations are ongoing challenges in wireless network coding. Furthermore, scalability concerns emerge as network size increases, potentially diminishing the efficiency of network coding schemes. Security is a critical limitation, as malicious nodes could exploit vulnerabilities in network coding implementations. Additionally, the practicality of real-world deployment may be hindered by the need for hardware and software support for network coding, which may not be readily available in existing wireless devices. Achieving consensus and standardization for network coding protocols and algorithms across different vendors and platforms can also be challenging. Addressing these challenges and limitations is crucial for the successful adoption of network coding in wireless network.

Conclusion

In conclusion, Network Coding is a powerful and innovative technique that has the potential to revolutionize data transmission and network performance. It offers numerous advantages, such as increased throughput, improved reliability, efficient resource utilization, and enhanced security. However, the adoption of network coding is not without its challenges, including integration complexities, computational overhead, interference management, and scalability issues. Despite these challenges, the benefits of Network Coding make it a compelling area of research and development for optimizing communication networks, both wired and wireless. As technology advances and solutions to these challenges emerge, network coding is likely to play an increasingly important role in shaping the future of data communication.

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