BIRZEIT UNIVERSITY

**Faculty of Engineering & Technology**
**Electrical & Computer Engineering Department**

**Information and Cdoing Theory-ENEE5304**

**Report**

# Network Coding

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In the late 1950's and 1960's people began to experiment with the idea of computer-to-computer communication, and all information, no matter the form, is stored in the computer's memory as a sequence of bits.

To send these bits they created hardware which could transmit a clocked sequence of electrical pulses along a wire. On the receiving end the computer would capture, store and convert the bits into the information they represent.

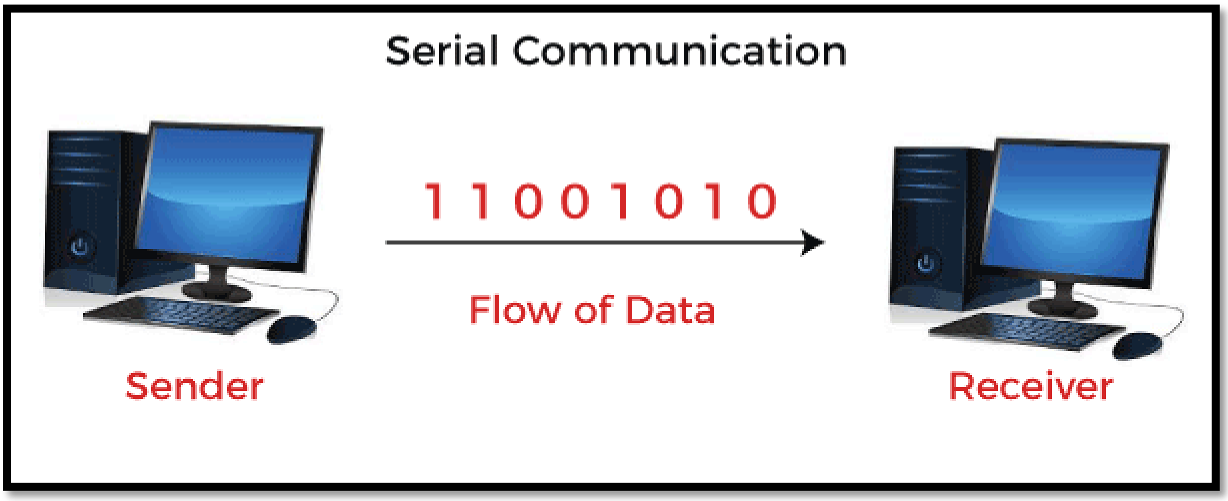


*Figure 1.Example of a sequence of bits being send*

Doing this with two computers, along a single line, is quite simple. But of course, other people wanted to connect their computers together, too. Leading to a computer network. One simple solution to make this network would be to connect all machines to all other machines, but as you add more and more computers this requires an impractical amount of line and it's incredibly wasteful.

Telephone networks at the time took a more practical approach, individuals were connected to a Hub (such as a city switchboard) which was a point through which many people could connect. At this hub would be an operator with a switchboard would manually patch people together by closing a circuit between them (known as a circuit switched network). So, if PERSON A wants to connect to PERSON B, they both get patched onto the long-distance line through the hub. the drawback of this method is nobody else in the network can use the long-distance line until they finish their conversation. We call this line the bottleneck of the network.

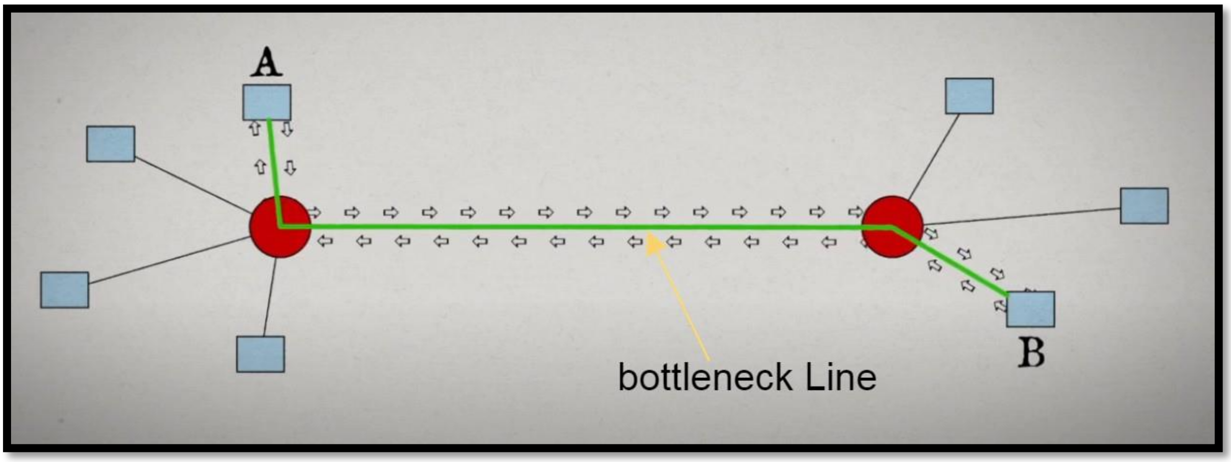


*Figure 2.Bottleneck Line*

By 1972 the designers of what we now call the internet were building ARPANET. It began as a small network of computers at universities on both sides of the country connected together. So, they came up with a clever way of weaving computer conversations together. by breaking up all digital messages into chunks known as packets. The packets arrive at the hub (Labeled by its source and destination), the hub sends packets from various sources on FIFO algorithm.

New cities were connected to hubs and those hubs were connected to each other. So more and more digital data needed to get squeezed down these long-distance lines. But there is a fundamental limit to how many bits you can squeeze down any line per second.

Instead of treating packets like cars, and sending them one at a time. The idea was to treat packets as numbers. And blend them together using mathematical operations, such as addition. Resulting in a new packet which contains a mixture of information from more than one packets.

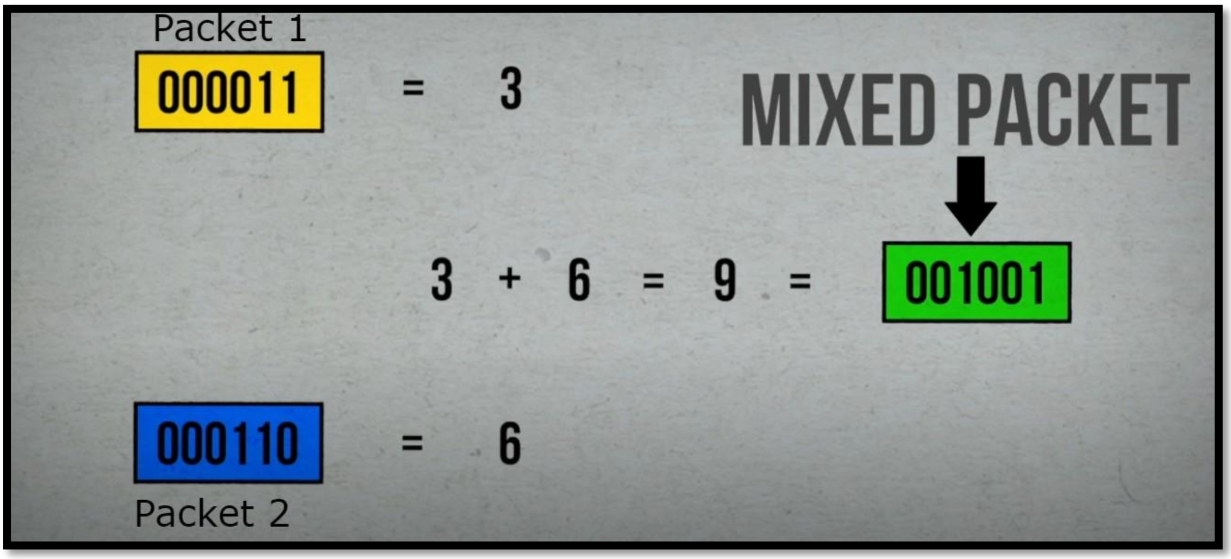


*Figure 3. Mixed Packets*

We treat each mixture as an equation, the receiving computer solves for the variables, or packets, it needs. This is in sharp contrast to how the internet was originally designed. Because it allows multiple packets to travel the same line at the same time, instead of having to get each packet in line and wait its turn. And this system practically works because computers can now do basic arithmetic operations needed to solve these linear equations incredibly fast, millions of times per second.

The first example that used in explaining the network coding is the Butterfly example.

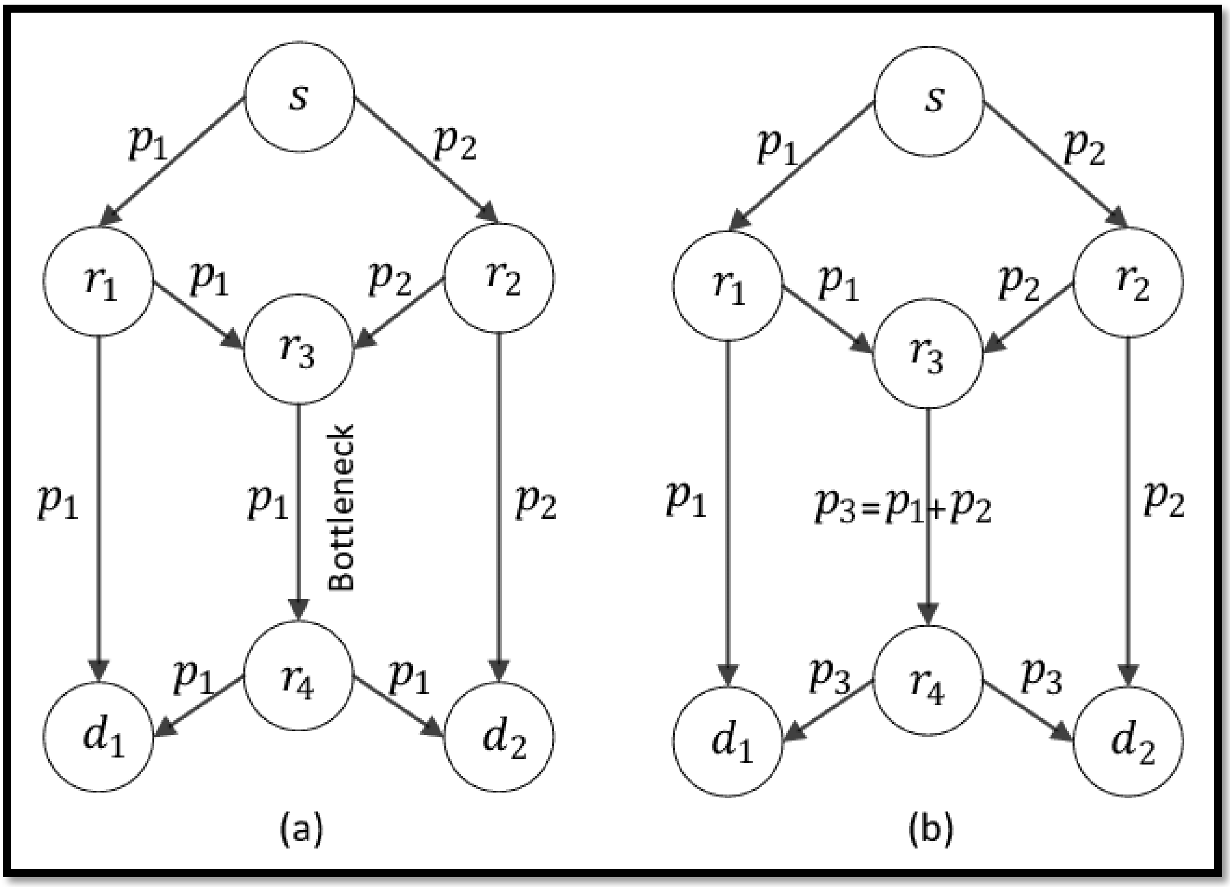


*Figure 4.Butterfly network*

As we can see in examples above S (source) want to send Packets P1 and P2 to both d1 and d2 destinations as we can see S can send P1 to d1 directly from root r1 and S can send P2 through r2 to d2 but when S want to send P2 to d1 path r3 r4 d2 is needed also P1 when it reached the d2 it needs to go through r3-r4-d1 as shown in a part of the figure above.

we can see that a bottleneck in r3-r4 is produced because p1 and p2 needs to use r3 in same time and r3 can handle only one of them so for example p1 is passed first so d1 gets P1 from r1 and P1 from r3-r4 and d2 has P2 from r2 and P1 from r3-r4 path so d2 received both P1 and P2 that it wanted to received but d1 received only p1 twice so it needs to wait for p2 when r3 can send it so that leads to latency or pause in video stream for example in d1 destination.

The network coding had the solution for this bottleneck in the switches by add all the packets using the xor operation for example in the past example we add P1 and P2 into one packet P3 and send it throw to r3 r4 path in this way we increased the bottleneck of the r3-r4 path and we replace the old store and forward way to solve which packet to pass with a faster and more efficient way.

With this method come the question how we can get the packets P1 and P2 from P3?

For example, in d1 we have already the packet P1 from path r1by xor it with p3 we can extract p2 from p3 and in the same way we can get p2 from p3.

To begin with the benefits of network coding, firstly, Latency; By obviating the necessity for ARQ mechanisms, network coding lowers latency. Coding-based solutions can recover from packet loss without needing to identify the individual lost packet, in contrast to store-and-forward systems that rely on ARQ. This enables the development of protocols that don't rely on acknowledgments to send fresh data.

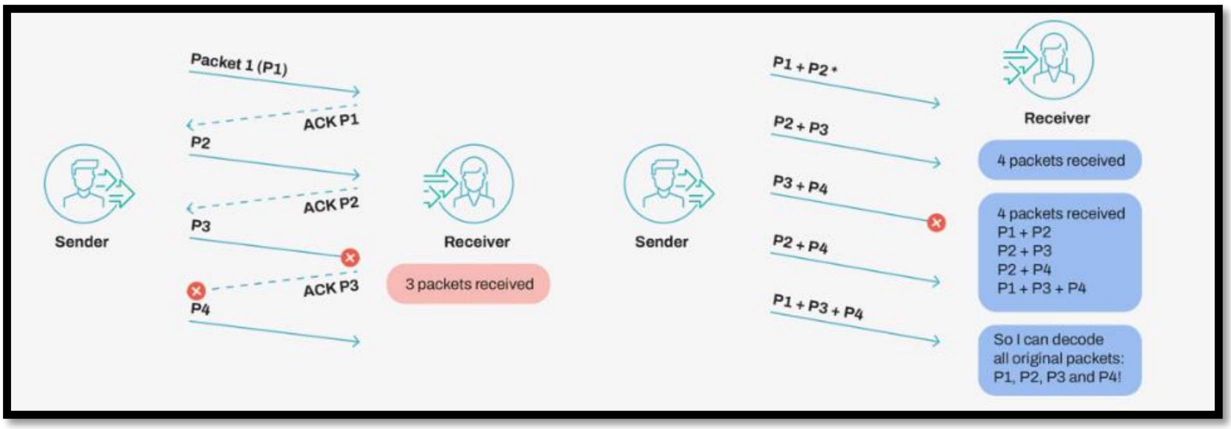


*Figure 5. Store-forward VS Network coding system*

Secondly, Scalability is improved by network coding, which optimizes the use of network resources. Coded packets serve numerous users in multicast/broadcast networks, effectively utilizing bandwidth and allowing for an increase in the number of users on the network.

Thirdly, Reliance, unlike conventional systems where packet loss occurs, network coding improves resilience by retrieving data when a node fails. Coded pathways enable redundancy without significant overhead in storage or network systems, providing a flexible trade-off between resource utilization and reliability.

Lastly, from a security standpoint, Network coding can offer benefits. Referring to figure 4.b, butterfly network, suppose an adversary manages to obtain only the packet p3 (= p1+p2), with these packets alone the adversary cannot obtain either p1 or p2; thus we have a possible mechanism for secure communication. One more thing in Network coding security, it encodes data packets before sending it, ensuring only the recipients can decode them and read their contents.

There are mainly 3 types of network coding schemes exits: Random Network coding, Vector Network coding, Linear Network Coding.

*Random Network Coding:*
Network nodes create and send coded packets that are randomly linear combinations of the packets they receive when using random network coding.

These coded packets contain data from numerous source packets, making it difficult for spectators to infer relevant information without being aware of the encoding coefficients.

Because random network coding is naturally hard to decode without knowing the coding coefficients, it is especially helpful in situations where security and data confidentiality are crucial.

*Vector Network Coding:*

A development of random network coding, vector network coding tries to give the encoded packets more structure.

Vector network coding enables nodes to create encoded packets using vectors over a finite field (often in a binary field or a field with a small number of elements) as opposed to completely random linear combinations.

Compared to completely random coding, this organized technique can increase the effectiveness of data retrieval at the receiving end.

*Linear Network Coding:*

In a more deterministic method known as linear network coding, network nodes apply linear operations to the incoming packets.

Each network node creates coded packets that are linear combinations of the input packets by combining incoming packets using linear algebraic operations (such as matrix multiplication).

Linear network coding, in contrast to random network coding, relies on established coefficients, making it more predictable while maintaining data transmission efficiency.

In conclusion, computer networking has advanced significantly from its earliest stages to the modern internet. Network coding is an important breakthrough that aids in overcoming data transmission problems. It enables numerous packets to transit at once, cutting down on delays and enhancing network efficiency. There are various forms of network coding, and each has advantages including improving security, effectiveness, and predictability.

Network coding has established its significance in the dynamic world of networking by facilitating faster, more dependable, and secure data transmission. The future of connectivity and communication will continue to be greatly influenced by technological advancements.

## References

[1] https://blog.codavel.com/how-network-coding-is-the-new-future-of-protocols

[2] https://www.techslang.com/definition/what-is-network-coding/

[3]https://www.researchgate.net/publication/30763733_A_Random_Linear_Network_Coding_Approach_to_Multicast

[4] https://www.researchgate.net/publication/265229690_Network_Coding_An_Introduction