UNIVERSITÄT OSNABRÜCK

Bricks for future Mobile Networking

Brick 3: Network Coding

Mobile Communication, WS 2014/2015, Kap.5

Prof. Dr. Nils Aschenbruck

Network Coding References

- Georg Carle, TU-München: Vorlesungsfolien „Network Coding“ WiSe2014/15
  http://www.net.in.tum.de/pub/nc2014/slides.pdf

- Muriel Médard, Frank H. P. Fitzek, Marie-José Montpetit, and Catherine Rosenberg: “Network Coding Mythbusting: Why It Is Not About Butterflies Anymore”, IEEE Communications Magazine, Vol.:52 (7), July 2014, pp. 177-183. http://dx.doi.org/10.1109/MCOM.2014.6852100

ACCEPTED FROM OPEN CALL

Network Coding Mythbusting: Why It Is Not About Butterflies Anymore

Muriel Médard, Frank H. P. Fitzek, Marie-José Montpetit, and Catherine Rosenberg

ABSTRACT

Network coding has been shown to have radical implications for improving current network and storage systems. Because of its disruptive nature, both in terms of techniques and implications, it had naturally led to debate and confusion. This article seeks to dispel some of the misconceptions still associated with network coding, which we term its enduring myths.

#6, and #7, appear widely in the literature, sometimes as central themes of papers, more often as assumptions. Maybe more importantly, these myths have recurred in conversations with hundreds of students, in our classes and in tutorials, and with a great number of colleagues who have some acquaintance with network coding, have not yet had the opportunity to study it at length, and seek to obtain some helpful context to guide their exploration of the subject. It is to this latter audience that this paper is addressed

What is Network Coding (NC)?

The basic principle of NC is to consider data in the network **not as immutable bits**, but as information that can be **combined algebraically**.

NC can be considered as a generalization of routing and forwarding:

- Routing determines best-paths from source to destination.
- Forwarding switches packets along one of these paths.
- Forwarding merely creates replicas of incoming packets, i. e., a packet's payload remains unaltered.

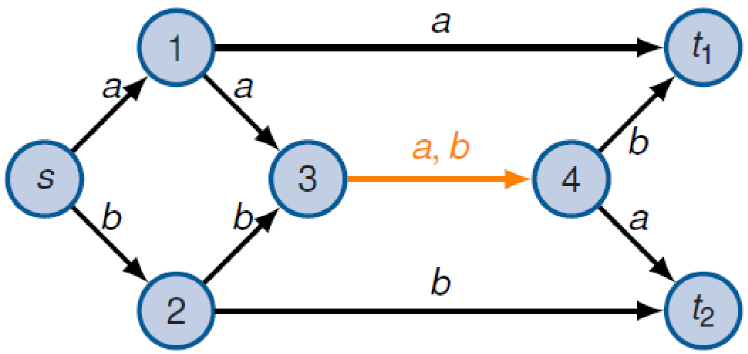
NC drops this restriction:

- Outgoing packets are arbitrary combinations of previously received packets.
- The process of combining packets in such a way is referred to as coding.
- Since coding does not only happen at the source but on any node in the network, the network codes on packets.

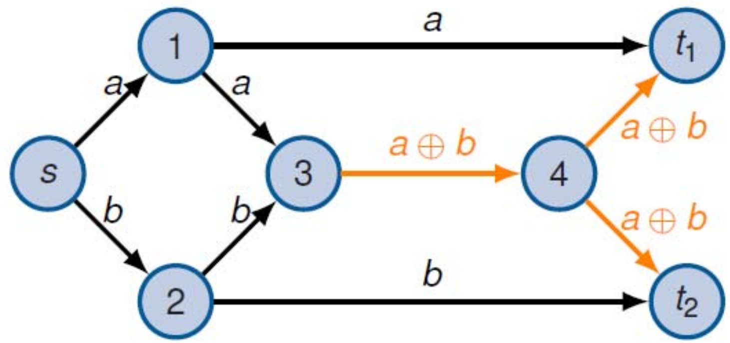
Source: Georg Carle, TU-München: Vorlesungsfolien „Network Coding" WiSe2014/15

Example: Butterfly

Source s transmits 2 packets a, b to both t_1, t_2 (multicast):



(a) Routing (with multicast)



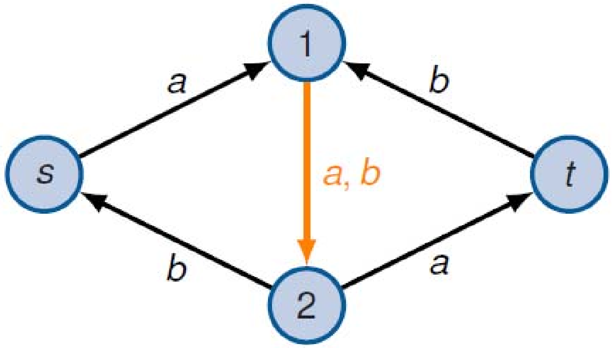
(b) Network Coding

- The link (3, 4) poses a bottleneck and must be used twice
- NC saves one transmission on the critical link (3, 4)
- t_1, t_2 can decode the missing packet by XORing the coded packet with a and b, respectively

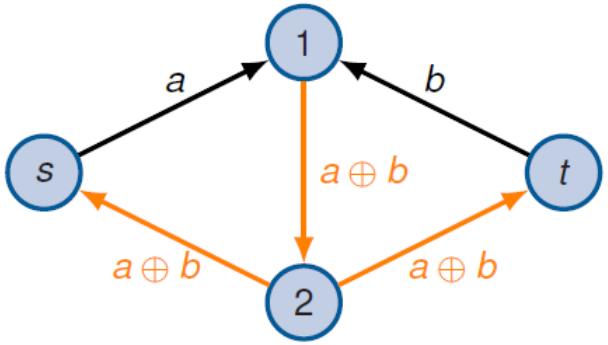
Source: Georg Carle, TU-München: Vorlesungsfolien „Network Coding" WiSe2014/15

Example: Diamond Network

Nodes s, t want to communicate with each other (bidirectional unicasts):



(a) Routing



(b) Network Coding

- The link $(1, 2)$ poses a bottleneck and must be used twice.

- NC saves again one transmission on the critical link $(1, 2)$.
- s, t know what they have sent and are thus able to decode.

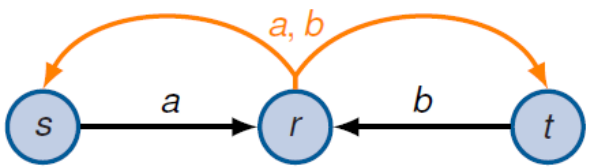
Source: Georg Carle, TU-München: Vorlesungsfolien „Network Coding" WiSe2014/15

Example: Wireless Relay Network

Nodes s, t want to communicate with each other (bidirectional unicasts):

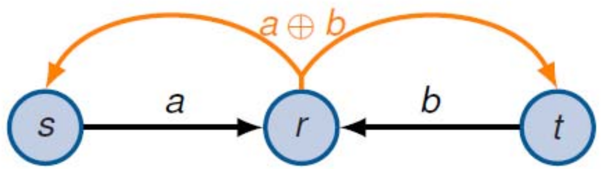
Note:

- Only 1 node can transmit at any time (otherwise transmissions would collide).
- A transmission by r is seen by both s, t (broadcast-nature of wireless networks).



(a) Routing

- The relay has to transmit a, b individually using 2 distinct broadcasts.
- Although s, t might overhear both transmissions, only one transmission is interesting for each node.



(b) Network Coding

- With NC, the relay transmits $a \oplus b$.
- Both s, t know what they have sent and are thus able to decode the missing packet.

Source: Georg Carle, TU-München: Vorlesungsfolien „Network Coding“ WiSe2014/15

Potential of Network Coding ...

MIT Technology Review

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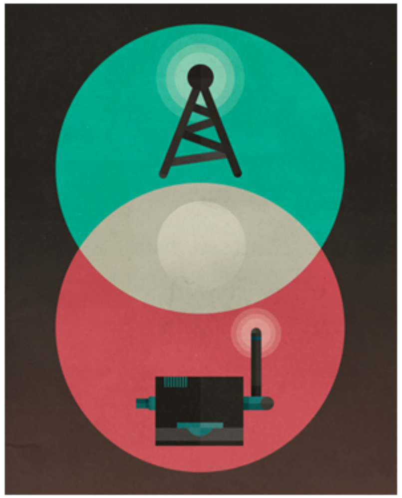
COMMUNICATIONS NEWS

A Bandwidth Brea

A dash of algebra on wireless netw
bandwidth tenfold, without new infra

By David Talbot on October 23, 2012



Academic researchers have im
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the network-clogging task of re
packets of data.

By providing new ways for mob
missing data, the technology n
wasteful process but also can s
streams from Wi-Fi and LTE—a
other approaches that toggle b
network will benefit from this te
Ng, vice president for research
NBC Universal.

Several companies have licens
technology in recent months, b
subject to nondisclosure agree
Medard, a professor at MIT's Research Laboratory of Elect
the effort. Elements of the technology were developed by re

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Angepasstes TCP beschleunigt ...

http://www.heise.de/newsticker/meldung/Angepasstes-TCP-beschleunigt-Sat-Verbindungen-2

Einloggen auf heise online

heise online

21.01.2014 10:00

Angepasstes TCP beschleunigt Sat-Verbindungen

Inmarsat will in diesem Jahr ein verbessertes Netzwerkprotokoll testen, um den Durchsatz von Satelliten-Internet potenziell zu verdoppeln.

Inmarsat will in diesem Jahr ein verbessertes Netzwerkprotokoll testen, um den Durchsatz von Satelliten-Internet potenziell zu verdoppeln, **berichtet [1]** *Technology Review* in seiner Online-Ausgabe. Das neue Verfahren, an

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Kodiermethode RLNC soll das Netz beschleunigen | iX - rekonq

Kodiermethode RLNC soll das N...

http://www.heise.de/ix/meldung/Kodiermethode-RLNC-soll-das-Netz-beschleunigen-221198

Einloggen auf heise online

heise online

News-Meldung vom 30.05.2014 20:01 Uhr

Kodiermethode RLNC soll das Netz beschleunigen

Messungen mit neuer Version eines Kodierverfahrens zeigen, wie sich die Datenübertragung im Netz beschleunigen lässt.

Random Linear Network Coding (**RLNC [1]**) heißt das Verfahren, das beim En- und Dekodieren die Datenübertragung im Netz in Fahrt bringen soll. Bei der üblichen Flusskontrolle können immer Fehler oder Datenverluste auftreten, die ein erneutes Übertragen von Paketen erfordern.

Das von Wissenschaftlern entwickelte RLNC soll ohne solche Rückgriffe auskommen. Es vermeidet Einbrüche im Durchsatz und verringert Wartezeiten in Anwendungen, indem es fehlende Informationen durch Korrekturverfahren regeneriert.

Mit der jüngst im Mai 2014 fertiggestellten Version 17 der Bibliothek **Kodo [2]** von Steinwurf ApS zeigten Untersuchungen einen erheblichen Geschwindigkeitsvorsprung gegenüber anderen Methoden. Verglichen wurde das Verfahren mit dem **Reed-Solomon-Code [3]**. Die Messungen fanden im SAN (Storage Area Network) auf einem Rechner mit Intels Core i7-4770 (3,4 GHz) statt. Die Implementierung des Reed-Solomon-Codes bietet Intel mit seiner Library **ISA-L [4]** an. Die Open-Source-Variante nennt sich Jerasure.

Bei Steinwurf ApS handelt es sich um einen Ausgründung der Universitäten in Ålborg und Massachusetts

Intra-session vs. inter-session coding

Intra-session coding:

- Only packets belonging to the same session may be coded together.
- Flows belonging to the same session may be coded together provided that bidirectional coding is allowed.
- Easier to implement, but fewer coding opportunities and thus potentially lower coding gain.

Inter-session coding:

- Packets of arbitrary flows / sessions may be combined.
- More coding opportunities but more also more complex.

Source: Georg Carle, TU-München: Vorlesungsfolien „Network Coding" WiSe2014/15

MORE

- MORE is a routing protocol for **stationary wireless meshes**
- MORE sits below the IP layer and above the 802.11 MAC
- source breaks up the file into **batches of K packets**
- When the MAC is ready to send, the source creates a **random linear combination of the K native packets** in the current batch and broadcasts the coded packet.
- sender attaches a **MORE header** to each data packet.
  - packet's code vector (which will be used in decoding),
  - the batch ID, etc.
- If the node is in the forwarder list, the arrival of this new packet triggers the node to **broadcast a coded packet**. To do so the **node creates a random linear combination of the coded packets** it has heard from the same batch and broadcasts it. Note that a linear combination of coded packets is also a linear combination of the corresponding native packets.

Further details:
Chachulski et al.: "Trading structure for randomness in wireless opportunistic routing", ACM SIGCOMM 2007.

Encoded TCP

Wi-Fi networks at MIT

- 2 percent of packets are typically lost => normal bandwidth: 1 Mbit/s
- with coded TCP: 16 Mbit/s

Fast-moving train

(New York-to-Boston Acela train - notorious for poor connectivity)

- 5 percent losses => 0.5 Mbit/s
- with coded TCP: 13.5 Mbit/s

Further details on the technology:
http://www.codeontechnologies.com/technology/

Source: http://www.technologyreview.com/news/429722/a-bandwidth-breakthrough/

Selected Network Coding Mythbusting

#1: NETWORK CODING REQUIRES "BUTTERFLY" TOPOLOGIES

- NC is not about finding butterflies in a network or re-engineering networks to create butterflies.

#2: NETWORK CODING REQUIRES COMPLICATED CODES AND WAITING FOR PACKETS

- "in practice, codes of the order of **eight bits** .. been found to be quite satisfactory"
- "each packet can easily bear **in its header the coefficients of the packets** from which it is formed. A late packet can simply be modeled as having a null coefficient associated with it. Thus, there is no need .. for waiting for packets to complete a block."

#4: NC IS ONLY FOR WIRELESS NETWORKS

- "Considerable gains have been shown in **network coded overlay networks** and for **peer-to-peer (P2P)** and **distributed storage** applications"

#9: THERE ARE NO PRACTICAL APPLICATIONS OF NC

- "even in its early days it had shown considerable value for **file transfer** and **P2P networking**"
- "TCP/NC has been shown to be **compatible with TCP** but improves its performance greatly"

for all myths see:
Médard et al.: "Network Coding Mythbusting: Why It Is Not About Butterflies Anymore", IEEE Communications Magazine, July 2014