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*H04L 27/18* (2006.01)      *H04W 40/00* (2009.01)

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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[Continued on next page]

## (54) Title: NETWORK CODING RELAY OPERATIONS

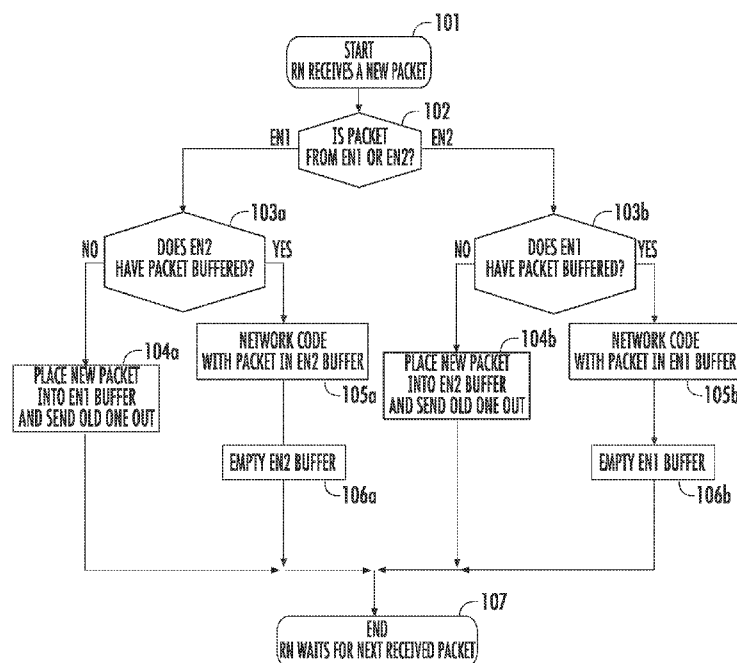


FIG. 7

(57) Abstract: A method for network coding of packets between End Nodes (ENs) and a Relay Node (RN) in wireless communications can be performed at the RN. This method may include: receiving a new packet at the RN from one of the ENs; determining the source node of the new packet at the RN; providing a buffer for each EN; determining whether the buffer associated with an EN that is not the source of the new packet (non-source buffer) has an existing packet buffered and based upon such determination, either: (1) storing the new packet in the EN buffer that is the source of the new packet on a condition that the non-source buffer is empty; or (2) network coding the new packet with the existing packet in the non-source buffer.



TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

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# INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2010/024725

## A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L1/00 H04L27/18 H04L27/34 H04W40/00  
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
H04L H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                    | Relevant to claim No. |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | XIANG HE ET AL: "On the energy-delay trade-off of a two-way relay network" INFORMATION SCIENCES AND SYSTEMS, 2008. CISS 2008. 42ND ANNUAL CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 19 March 2008 (2008-03-19), pages 865-870, XP031282985<br>ISBN: 978-1-4244-2246-3 | 1-3, 19,<br>20, 27-29 |
| Y         | section II, paragraph 2, items 1) and 2)                                                                                                                                                                                                                              | 4-11,<br>15-17        |
| A         | US 2008/089333 A1 (KOZAT ULAS C [US] ET AL) 17 April 2008 (2008-04-17)<br>figure 7<br>paragraph [0084] - paragraph [0087]<br>-----<br>-/--                                                                                                                            | 1-5, 19,<br>20, 27-29 |



Further documents are listed in the continuation of Box C.



See patent family annex.

### \* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

27 October 2010

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17/11/2010

Name and mailing address of the ISA/

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## INTERNATIONAL SEARCH REPORT

International application No

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## C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Relevant to claim No.    |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| A         | <p>MAHMINO A ET AL: "Guaranteed Packet Delays with Network Coding"<br/> SENSOR, MESH AND AD HOC COMMUNICATIONS AND NETWORKS WORKSHOPS, 2008. SECON WORKSHOPS '08. 5TH IEEE ANNUAL COMMUNICATIONS SOCIETY CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 16 June 2008 (2008-06-16), pages 1-6, XP031287482<br/> ISBN: 978-1-4244-2562-4<br/> section IV-A, paragraph 1<br/> section IV-B, item 2)</p> <p>-----</p>                                                                                                                           | 1-5, 19,<br>20, 27-29    |
| Y         | <p>LARSSON P ET AL: "Coded Bi-directional Relaying"<br/> IEEE VEHICULAR TECHNOLOGY CONFERENCE; 20060507, [Online]<br/> vol. 2, pages 851-855, XP002489802<br/> Retrieved from the Internet:<br/> URL: <a href="http://www.ericsson.com/technology/research_papers/wireless_access/doc/Coded_Bi-directional_Relaying.pdf">http://www.ericsson.com/technology/research_papers/wireless_access/doc/Coded_Bi-directional_Relaying.pdf</a><br/> [retrieved on 2008-07-24]<br/> page 851, right-hand column, last paragraph</p> <p>-----</p> | 4, 5                     |
| Y         | <p>KATTI S ET AL: "XORs in the Air: Practical Wireless Network Coding"<br/> IEEE / ACM TRANSACTIONS ON NETWORKING, IEEE / ACM, NEW YORK, NY, US, vol. 14, no. 3, 1 June 2008 (2008-06-01), pages 497-510, XP011226939<br/> ISSN: 1063-6692</p> <p>-----</p>                                                                                                                                                                                                                                                                            | 6-11,<br>15-17           |
| A         | <p>sections V-A and VI-A<br/> section VIII, paragraph 1</p> <p>-----</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 12, 13                   |
| A         | <p>US 6 247 058 B1 (MILLER JOHN P [US] ET AL)<br/> 12 June 2001 (2001-06-12)<br/> * abstract</p> <p>-----</p>                                                                                                                                                                                                                                                                                                                                                                                                                          | 6-13                     |
| A         | <p>Dan-Cristian Tomozei: "WIRELESS PROTOCOLS USING NETWORK CODING: REPORT ON ON STATE-OF-THE-ART"<br/> ICT - Information and Communication Technologies, The N-CRAVE Consortium</p> <p>22 January 2009 (2009-01-22), pages 1-29, XP002606798<br/> Retrieved from the Internet:<br/> URL: <a href="http://www.n-crave.eu/images/pdf/D2.1.pdf">http://www.n-crave.eu/images/pdf/D2.1.pdf</a><br/> [retrieved on 2010-10-14]<br/> the whole document</p> <p>-----</p>                                                                     | 1-13,<br>15-17,<br>19-29 |
|           | -----<br>-/--                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                          |

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2010/024725

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                      | Relevant to claim No. |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | YONG HUANG ET AL: "TCP Performance in Coded Wireless Mesh Networks"<br>SENSOR, MESH AND AD HOC COMMUNICATIONS AND NETWORKS, 2008. SECON '08. 5TH ANNUAL IEEE COMMUNICATIONS SOCIETY CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA,<br>16 June 2008 (2008-06-16), pages 179-187,<br>XP031282591<br>ISBN: 978-1-4244-1777-3<br>section IV-C                                                                                    | 15-17                 |
| A         | HAN LIU ET AL: "Network Coding for Information Exchange between Multiple Nodes in Wireless Networks"<br>VEHICULAR TECHNOLOGY CONFERENCE, 2008. VTC SPRING 2008. IEEE, IEEE, PISCATAWAY, NJ, USA, 11 May 2008 (2008-05-11), pages 51-55, XP031255487<br>ISBN: 978-1-4244-1644-8<br>sections III-B and D                                                                                                                  | 15-17                 |
| A         | Various: "One-way compression function"<br>Wikipedia.org<br><br>19 February 2009 (2009-02-19), pages 1-5,<br>XP002606799<br>Retrieved from the Internet:<br>URL: <a href="http://en.wikipedia.org/w/index.php?title=One-way_compression_function&amp;oldid=271848714">http://en.wikipedia.org/w/index.php?title=One-way_compression_function&amp;oldid=271848714</a><br>[retrieved on 2010-10-20]<br>the whole document | 15                    |
| X         | LEI XIAO ET AL: "A Network Coding Approach to Cooperative Diversity"<br>IEEE TRANSACTIONS ON INFORMATION THEORY, IEEE, US,<br>vol. 51, no. 10,<br>1 October 2007 (2007-10-01), pages 3714-3722, XP011192551<br>ISSN: 0018-9448<br>section III-A<br>figure 3                                                                                                                                                             | 21                    |
| X         | JIE HOU ET AL: "Distributed turbo coding schemes for asymmetric two-way relay communication"<br>TURBO CODES AND RELATED TOPICS, 2008 5TH INTERNATIONAL SYMPOSIUM ON, IEEE, PISCATAWAY, NJ, USA LNKD-<br>DOI:10.1109/TURBOCODING.2008.4658704,<br>1 September 2008 (2008-09-01), pages 237-242, XP031353694<br>ISBN: 978-1-4244-2862-5<br>section III-B                                                                  | 21                    |

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2010/024725

## Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☒ Claims Nos.: 22-26  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:  
see FURTHER INFORMATION sheet PCT/ISA/210
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
  
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
  
3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:  
1-13, 15-17, 19-21, 27-29
  
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 22-26

The subject-matter of claims 22-26 is unclear and not supported by the description to such an extent that no meaningful search can be carried out. Claims 22-26 depend on claim 21. Claim 21 defines that network coding of packets is performed before channel coding. As far as claim 22 can be understood, claim 22 defines that two packets are modulated by QPSK and BPSK modulation, respectively, which are then modulated into m modulation symbols. Basis for this can be found in the description in paragraphs 49-58. In this case, the mapping onto modulation symbols as e.g. described in relation to equ. (1) in paragraph 53 as such implements the network coding operation. It is clear that paragraphs 49-58 are directed to the case of network coding after ( ) channel coding (see sub-title in paragraph 49: "Network coding the coded packets", which means that the network coding is based on already channel coded packets). Moreover, it is not evident how the modulated symbols (which represent the network coded symbols) can afterwards be channel coded. In fact, network coding two packets by modulation, as defined in claim 22, is incompatible with a further channel coding operation after the network coding operation, as defined in claim 21. As a result, the features of claim 22 are incompatible with the features defined in claim 21. The same is true for the subject-matter defined in claim 24. Moreover, claim 23 defines a further network coding operation after the modulation which is defined in claim 22. Since the modulation defined in claim 22 already implements the network coding operation, a further network coding operation as defined in claim 23 is obscure. Also the subject-matter of claims 25 and 26 is not supported by the description. Paragraphs 72 to 82, which are the basis for the subject-matter of claims 25 and 26, are clearly directed to network coding after channel encoding. As a result, the features of claim 25 and 26 incompatible with the features defined in claim 21.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.2), should the problems which led to the Article 17(2) declaration be overcome.

## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-5, 19, 20, 27-29

Network coding is done using a XOR operation that does not require identical number of bits, as defined in claim 4, for example by rate matching or by using signal constellations of different sizes.

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2. claims: 6-13

A matching procedure rates pairs of packets based upon packet length and the duration of time that a packet has been stored in an EN buffer, as defined in claim 12.

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3. claim: 14

(identified when performing the search for claim 6) On a condition that the RN does not receive a packet from an EN for a certain length of time, the method further comprising transmitting already-buffered packets starting with an oldest packet either with or without network coding, as defined in claim 14.

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4. claims: 15-17

Assigning each packet a Network Coding Index (NCI) comprising a modulus equal to or greater than a network coding buffer size N, as defined in claim 15.

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5. claim: 18

Storing no more than M packets for each EN wherein each buffer has a size N, wherein each buffer has  $N > M$  packet storage capacity, wherein  $N - M$  is greater than latency required for processing and transmitting packets, as defined in claim 18.

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6. claims: 21-26

Network coding packets before channel coding wherein a single packet is channel encoded.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2010/024725

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| US 2008089333 A1                          | 17-04-2008          | WO 2008048651 A2           | 24-04-2008          |
| US 6247058 B1                             | 12-06-2001          | NONE                       |                     |