(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 July 2002 (11.07.2002)

PCT

(10) International Publication Number
WO 02/054661 A1

(51) International Patent Classification[7]: H04L 7/00, 12/54

(21) International Application Number: PCT/NO01/00515

(22) International Filing Date:
28 December 2001 (28.12.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
20006683 28 December 2000 (28.12.2000) NO

(71) Applicant *(for all designated States except US)*: **ABB RESEARCH LTD.** [CH/NO]; c/o ABB AS, Corporate Research Center, Postboks 90, N-1375 Billingstad (NO).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **HOLMEIDE, Øyvind** [NO/NO]; Orionveien 12, N-0489 Oslo (NO). **SKEIE, Tor** [NO/NO]; Solengveien, N-3512 Hønefoss (NO). **APNESETH, Christoffer** [NO/NO]; Sigurdsgate 20C, N-0650 Oslo (NO). **JOHANNESSEN, Svein** [NO/NO]; Dalsveien 12, N-0376 Oslo (NO). **LØKSTAD, Trond** [NO/NO]; Fjordvangveien 73, N-1450 Nesoddtangen (NO).

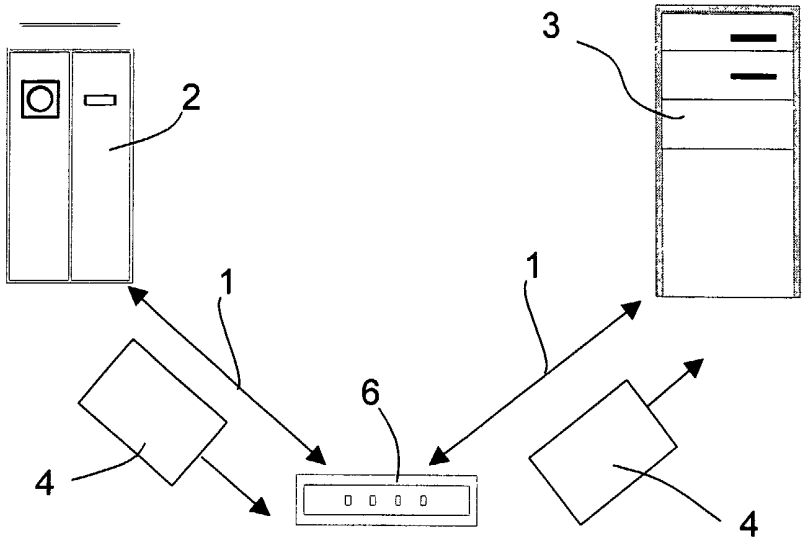
(74) Agent: **OSLO PATENTKONTOR AS**; Postboks 7007M, N-0306 Oslo (NO).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),

[Continued on next page]

(54) Title: METHOD FOR SYNCHRONIZATION IN A LOCAL AREA NETWORK INCLUDING A STORE-AND-FORWARD DEVICE



(57) Abstract: The present invention relates to a method for identifying inaccurate time measurements in a local area network. The local area network comprises a sending device (2), such as a time client, a destination device (3), such as a timeserver, and a switching device and/or a store-and-forward device (6). A time request packet (4) is rejected if it arrives at the time client or timeserver within a given or calculated minimum distance from the preceding network packet. The time request packet (4) is also rejected if it falls outside a set of calculated error limits based on a set of estimates. Those estimates are kept in the time client memory and updated according to a given set of rules.

WO 02/054661 A1

Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

— *of inventorship (Rule 4.17(iv)) for US only*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Method for synchronization in a local area network including a store-and-forward device

Field of the invention

A method for identifying inaccurate time measurements in a local area network incorporating a central switch and/or a store-and-forward device.

Background of the invention

Several schemes exist for synchronizing a time-of-day clock in one node, such as a time client, to a reference time-of-day clock in another node, such as a timeserver, over a local area network (LAN). Most of the time-of-day clocks attain their stated accuracy only when a network transfer delay between the time client and the timeserver is constant. Introduction of switched Ethernet created a class of local area networks where network capacity was greatly enhanced at the expense of a predictable delay between the time one network node transmits a time request packet and the time the destination node receives it. A reason for this is that the link to the destination node may be busy with other packets when the aforesaid packet is ready to be placed on that link. In such cases the packet is stored in the switch, which therefore is also a store-and-forward device, until the link to the destination node is free.

Summary of the invention

The object of the invention is to provide a method for identifying inaccurate time measurements in a local area network incorporating a central switch and/or a store-and-forward device.

This object is achieved by a method according to the independent claims 1 and 2.

A network incorporating a store-and-forward device, like the switch in a switched Ethernet network, has two distinct

sources of delay. The first source of delay is the connection from the sending device, such as the time client, to the store-and-forward device and the second source of delay is the connection from the store-and-forward device to the destination device, such as the time server 4. This invention will address both sources, using two distinct algorithms.

Brief description of the drawings

Fig. 1 is a schematic block diagram of a computer network, such as a LAN, comprising a time client, a timeserver and a central switch and/or a store- and forward device.

Fig. 2 shows an example of normal packet arrivals and queued packet arrivals.

Fig. 3 shows an example of accepting or rejecting a measurement based on estimates.

Detailed description of the preferred embodiments

Figure 1 shows a schematic block-diagram of a computer network 1, such as a local area network, comprising a time client 2 and a timeserver 3. A switching device and/or a store-and-forward device 6 are/is in the path between the time client and the timeserver. A time request packet 4 is transmitted from the time client 2 to the timeserver 3 and from the timeserver to the time client.

It is presupposed that the time request packets 4 are time stamped at the end of the time request packets. The reason for this is that it is only ensured that a time request packet has been fully received or transmitted at the end of the time request packet. If the time request packet is time stamped before the end, the time request packet might be aborted before transmission or reception has been completed.

In the following examples the time client 2 is working as a sending device and the timeserver 3 is working as a destination device. This should be seen as an example only. When the time request packet 4 is transferred from the timeserver 3 to the time client 2 the timeserver is working as a sending device and the time client is working as a destination device

When a time request packet 4 is transmitted from the store-and-forward device 6 to the timeserver 3, i.e. the destination device, the time request packet might be stored in the store-and-forward device 6 waiting for other packets to finish using the link to the timeserver. The time request packet 4 will be sent as soon as possible. This means that it will be sent after the preceding packet followed by a specified Minimum Interpacket Gap, shown in figure 2. The specified Minimum Interpacket Gap for Ethernet is given by the IEEE 802.3 and ISO 8802/3 standards. Since the length of the time synchronization packet is known as well as the length of the additional bits associated with packet transmission, such as preamble, checksum etc., a minimum time distance between the end of the preceding packet and the end of the time synchronization packet may be calculated. The time distance between the end of the preceding packet and the end of the time request packet 4 is measured in the destination device, in this example the timeserver 3. If the measured time distance is within a given tolerance of this minimum time distance t, it is concluded that the time request packet 4 was delayed in the switch and/or the store-and-forward device and therefore the time measurement associated with it will be inaccurate. The delayed packet will not be used for time calculations. Figure 2 shows an example of normal time request packet arrivals A and queued time request packets arrival B.

If the measured time distance is greater than the Minimum Interpacket Gap the time request packet 4 has not been delayed in the switch and/or store-and-forward device and

the time stamps may be used to synchronize the time client 2 and the time server 3.

If there are delays on the link from the sending device to the store-and-forward device, an alternative procedure for validating the time stamp accuracy must be used.

Figure 3 shows how the time stamp accuracy is validated when it has been a delay on the link 1 from the sending device, for example, the time client 2, to the switching device and/or store-and-forward device. This procedure is based on a certain degree of confidence in the local time-of-day clock. This confidence is expressed in four variables: estimated relative local frequency deviation dfR, estimated local frequency accuracy d2fR, estimated local time precision dtP and a confidence level. Start values for the estimated relative local frequency deviation dfR and the estimated local frequency accuracy d2fR are stored in the time client when the time client is manufactured, together with a comparison value for the confidence level variable. The confidence level variable always starts at 0 and as long as it is less than the comparison value, there is a low confidence in the estimates. When the confidence level variable is greater than or equal to the comparison value, there is a high confidence in the estimates.

When a new time adjustment tA is calculated from the time stamps, it is decided whether to keep the adjustment or reject it according to, for example, the following algorithm:

1. First an upper acceptance level tH or a lower acceptance level tL for the new time adjustment tA is calculated:

```
tB = tP + (tR - tP)*(1 + dfR)
dtB = dtP + (tR - tP)*d2fR
tH = tB + dtB
tL = tB - dtB
```

where tP is the value of the local clock at a previously accepted time adjustment, tR is the value of the local clock at the current time request, dfR is the estimated relative local frequency deviation, dtP is the estimated local time precision at the previously accepted time adjustment and d2fR is the estimated local frequency accuracy at the same point in time. The range between the upper acceptance level tH and the lower acceptance level tL is called the error range.

2. If tA falls within the error range, tA is accepted and used to update local time, estimated local frequency and estimated frequency drift. In addition, the confidence level is increased up to a predefined limit.

3. If there is a high confidence in our estimates and tA does not fall within the error range, tA is rejected and the confidence level in our estimates is decreased to a value greater than 0.

4. If there is a low confidence in our estimates and tA does not fall within the error range, there are several options. A first option is to reject tA, decrease the confidence level and hope for a better tA in the future.

A second option is to introduce a new set of estimates together with a time-of-day offset. When the new set of estimates has been introduced every new time adjustment tA must be checked against every set of estimates until one of the confidence levels becomes high. At that point in time, that set of estimates is kept and the others are deleted. The next time adjustment tA will fulfill the requirements in either the time client 2 or the timeserver 3.

Claims

1. Method for identifying inaccurate time measurements when running time synchronization on a local area network, the local area network comprising a sending device (2), a destination device (3) and a switching device and/or a store-and-forward device (6) arranged on a path (1) between the sending device (2) and the destination device (3), c h a r a c t e r i z e d b y
rejecting time request packets (4) that arrive to the destination device (3) within a given time interval t from a preceding network packet.

2. Method for identifying inaccurate time measurements when running time synchronization on a local area network, the local area network comprising a sending device (2), a destination device (3) and a switching device and/or a store-and-forward device (6) arranged on a path (1) between the sending device (2) and the destination device (3), c h a r a c t e r i z e d b y
keeping one or more estimates of the accuracy and precision of the local time-of day clock in a memory in the sending device (2) and accepting or rejecting the new time measurement based on a set of calculations made from these estimates.

3. Method according to claim 2, c h a r a c t e r i z e d i n that the sending device (2) is a time client.

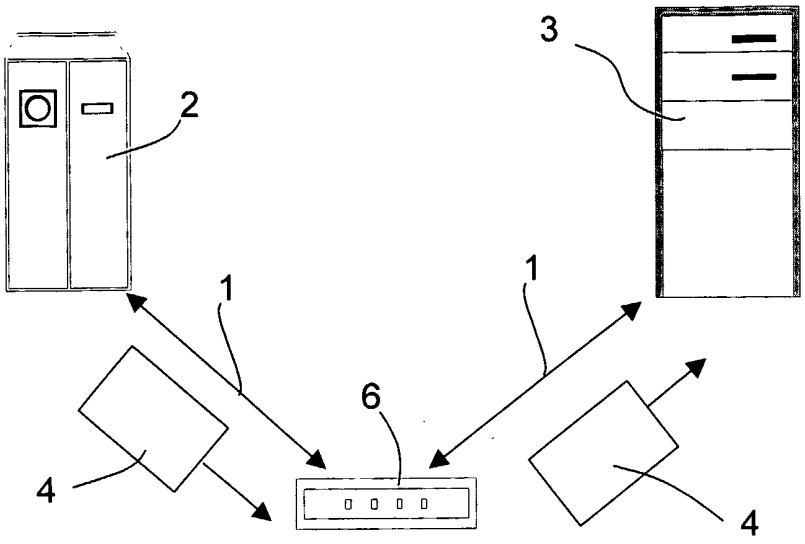


Fig 1

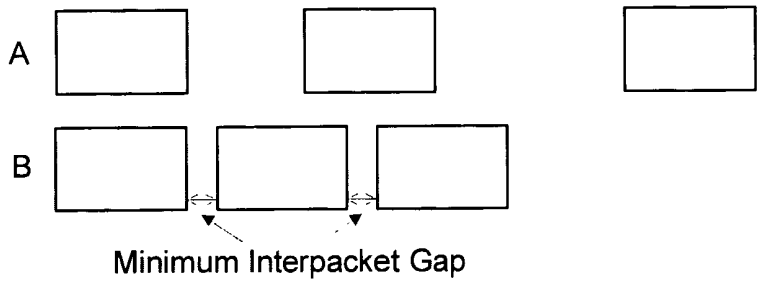


Fig 2

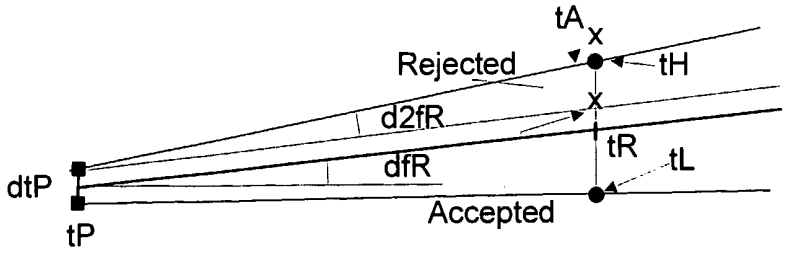


Fig 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 01/00515

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04L 7/00, H04L 12/54
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)

IPC7: H04L, H04J

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 0150657 A2 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)), 12 July 2001 (12.07.01), page 3, line 1 - page 5, line 28; page 25, line 27 - page 27, line 20, figures 5-7,18, abstract --	1-3
A	US 5025457 A (AHMED, H.M.), 18 June 1991 (18.06.91), column 2, line 22 - column 4, line 10, figures 1-3d, claims 1-34, abstract --	1-3
A	US 5812749 A (FERNANDEZ, L.R. ET AL), 22 Sept 1998 (22.09.98), figures 1-2c, claims 1-21, abstract, the whole document --	1-3

[X] Further documents are listed in the continuation of Box C. [X] 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 application or patent 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	Date of mailing of the international search report
3 April 2002	09 -04- 2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Ismar Hadziefendic /OGU Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 01/00515

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0697774 A (HEWLETT-PACKARD COMPANY), 21 February 1996 (21.02.96), page 2, line 43 - page 3, line 47, claims 1-12, abstract -- --------	1-3

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/01/02

International application No.
PCT/NO 01/00515

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0150657 A2	12/07/01	AU 2718301 A	16/07/01
US 5025457 A	18/06/91	AT 140350 T	15/07/96
		AU 628504 B	17/09/92
		AU 5231990 A	01/11/90
		CA 2014259 A,C	21/10/90
		DE 69027701 D,T	06/02/97
		EP 0394051 A,B	24/10/90
		ES 2090095 T	16/10/96
		GR 3021238 T	31/01/97
		JP 2296434 A	07/12/90
		JP 2612505 B	21/05/97
US 5812749 A	22/09/98	NONE	
EP 0697774 A	21/02/96	NONE	