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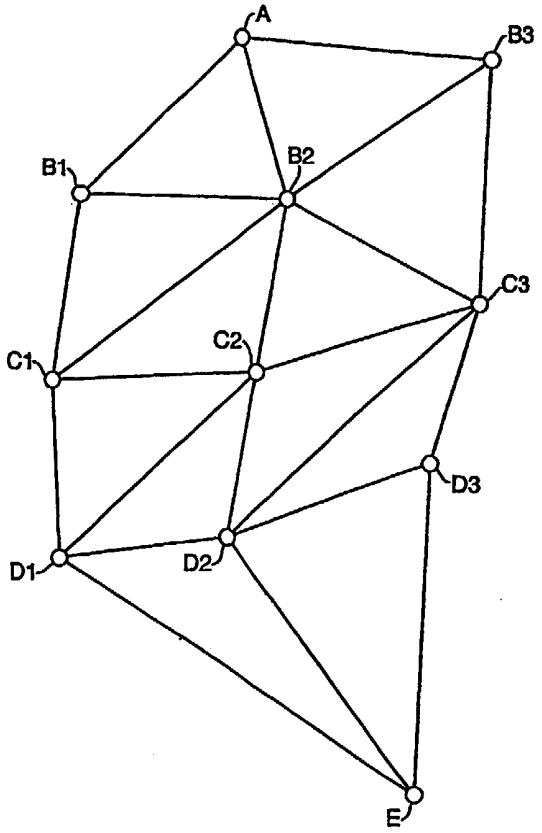
(54) Abstract Title
Routing of packets in a mobile radio network

(57) A mobile radio network has a plurality of nodes including intermediate nodes for passing information in the form of packets from a preceding node to a succeeding node. Each intermediate node transmits a signal indicating that it is available to pass information and also transmits an acknowledgement signal transmitted by a destination node when the information reaches the destination node. The nodes select an intermediate node on the basis of the availability signal. If an intermediate node does not transmit an acknowledgement signal after a packet is transmitted to it a predetermined number of times then this is detected by the other nodes and it is not selected for the passage of information.



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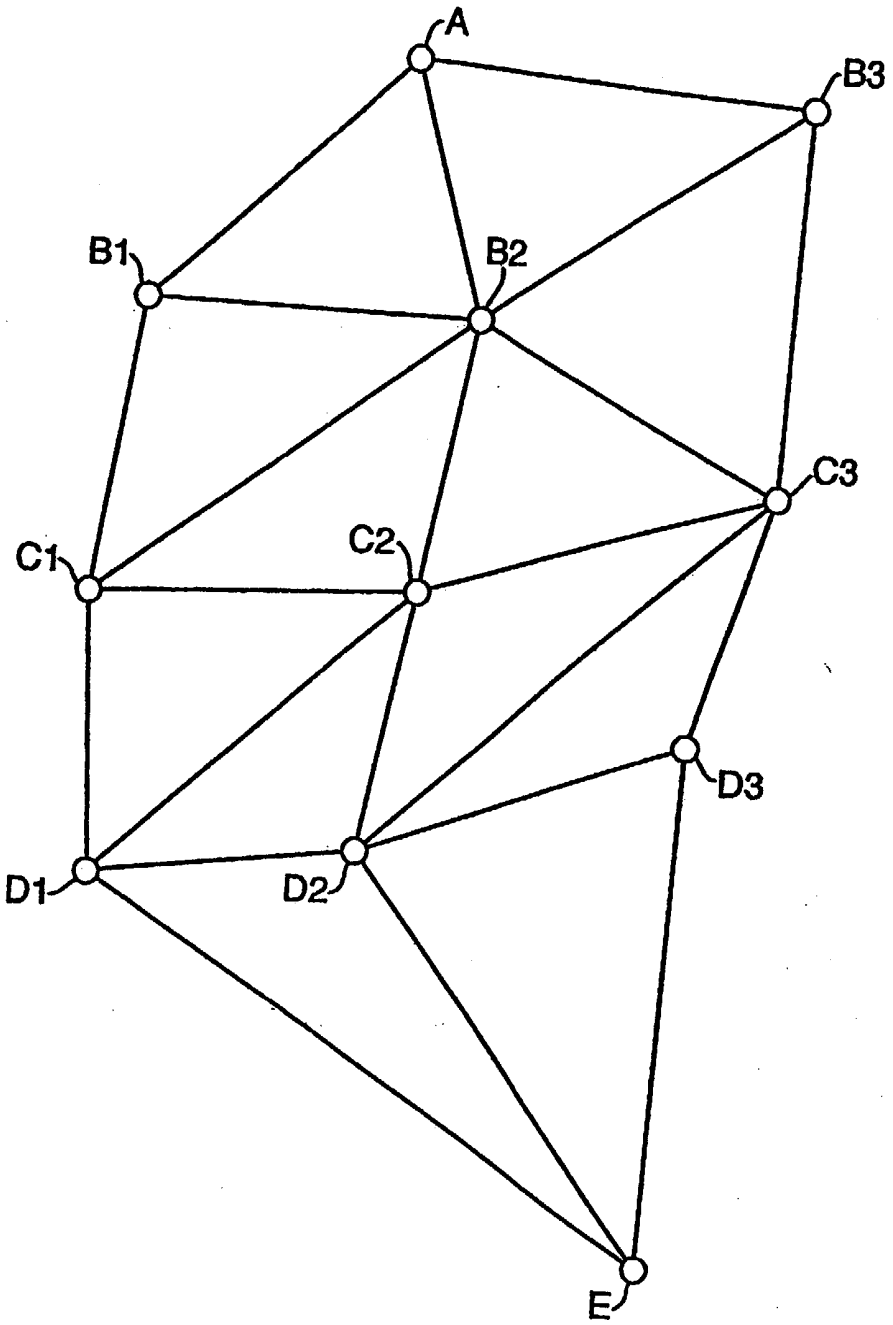
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.


A
B3
B1
B2
C3
C1
C2
D3
D1
D2
E

MOBILE RADIO NETWORKS

The invention relates to mobile radio networks and methods for their operation.

A mobile radio network may comprise a plurality of nodes including intermediate nodes for passing information from a preceding node to a succeeding node. Each intermediate node transmits a signal indicating that the node is available to pass information and also transmits an acknowledgement signal transmitted by a destination node when the information reaches the destination node.

It is a problem with such systems that an intermediate node may transmit an availability signal and yet not pass information because the intermediate node is faulty (a "sink" node). Although a node transmitting information to the sink node notes the absence of an acknowledgement signal, this results only in re-transmission of the information by the transmitting node and this may be to the sink node.

According to the invention, there is provided a mobile radio network comprising an originating node, a destination node and a plurality of intermediate nodes, the originating node transmitting information to the destination node along a path including a succession of intermediate nodes in which each preceding node selects a succeeding intermediate node on the basis of an availability signal transmitted by the intermediate nodes, each intermediate node in the path transmitting an

acknowledgement signal from the destination node to the originating node on receipt by the destination node of said information, each node monitoring the transmission of information and associated acknowledgement signals by the intermediate nodes and not selecting an available intermediate node if said node, a predetermined number of times, transmits information but does not transmit an associated acknowledgement signal.

The following is a more detailed description of an embodiment of the invention, by way of example, reference being made to the accompanying drawing which is a simplified schematic view of a mobile radio network.

A mobile radio network is formed from a plurality of nodes. These nodes include a calling node A and a network node E. It will be appreciated that there will in practice be a large number of calling nodes A and possibly more than one network node E. The calling node A may be mobile.

A number of intermediate nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 are provided for conveying information between the calling node A and the network node E. The passage of information is two way i.e. either from the calling node A to the network node E or from the network node E to the calling node A.

Information is transmitted from the calling node A to the network node E in the following way. Each intermediate node B1,B2,B3,C1,C2,C3,D1,D2,D3 transmits a signal indicating that the intermediate node B1,B2,B3,C1,C2,C3,D1,D2,D3 is available for the passage of information. The calling node A receives such signals from those intermediate nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 which are in range. In the accompanying diagram, three intermediate nodes B1,B2,B3 are in range and the calling node A receives signals from these nodes B1,B2,B3 indicating that they are available for the passage of information.

The calling node A transmits information in packets to a first selected one of the intermediate nodes B2. The selection may, for example, be made on the basis of signal strength. The selected first intermediate node B2 receives each packet and relays it to a selected in-range second intermediate node C3. In this regard, each intermediate node B1,B2,B3,C1,C2,C3,D1,D2,D3 also receives the availability signals from other intermediate nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 which are in range. The first intermediate node B2 that has the packet selects the second intermediate node to which it transmits the packet on an ad hoc basis by opportunistic relay. The transmission continues with the intermediate node C3 selecting, for example, the third intermediate node D3 which, in turn, passes the packet to the network node E.

On receipt of the packet, the network node E sends out an acknowledgement. This acknowledgement is signed using a public key digital signature algorithm where the

public key is known to all the other nodes. An example of such a signature algorithm is the low-exponent Rivest/Shamir/Adleman public key crypto system where the public key of the pair is a small integer. This acknowledgement is passed back to the calling mode A. This may be via the intermediate nodes D3,C3,B2 or by another path, in a reversal of the manner described above. On receipt, the calling node A verifies the signed acknowledgement with the public key.

The passage of a packet and the receipt of an acknowledgement by an intermediate node B1,B2,B3,C1,C2,C3,D1,D2,D3 is also read by the other intermediate nodes B1,B2,B3,C1,C2,C3,D1,D2,D3.

It is possible that one of the intermediate nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 is transmitting an availability signal but is not, in fact, passing packets. The system detects this in the following way.

If the calling node A receives an availability signal from an intermediate node B2, transmits a packet to intermediate node B2 but receives no acknowledgement from B2 this may be because the node B2 is faulty or because one of the succeeding nodes in the chain is faulty. In the absence of an acknowledgement, the calling node A initially only records the possibility of intermediate node B2 being faulty and re-transmits the packet. At the same time, any of the other intermediate nodes B1,B3,C1,C2,D1,D2, in range may also be recording the transmission of packets and the receipt/non receipt

of an acknowledgement from the first, second and third intermediate nodes B2,C3,D3 within range.

If the intermediate node B2 is faulty, a subsequent attempt by the calling node A to transmit a packet via B2 will also result in the absence of an acknowledgement. Since the transmission of packets from the intermediate node B2 to the network node E is on an ad hoc basis, the chances of the packet being transmitted via both the previously selected second and third intermediate nodes C3 and D3 is rather small, but the chance of the transmission including either intermediate node C3 or intermediate node D3 is not negligible. For this reason, the absence of an acknowledgement from intermediate node B2 is not necessarily an indication that intermediate node B2 is a sink node. Accordingly, the absence of a second acknowledgement is noted by the calling node A and the packet re-transmitted. For a network there will be a predetermined number of times a packet must be transmitted without the receipt of an acknowledgement before an algorithm at the calling node A judges that the intermediate node B2 is a sink node. For a very simple network, the number may be one but, in general, it will be a number greater than one. Once that number is reached, the calling node A no longer selects the first intermediate node B2 but sends it to another intermediate node, say B3. The algorithm for detecting a sink node need not require a fixed successive number, it could for instance require detection of m absences of acknowledgements from n signals where n>m. The numbers m and n and the fixed successive number may vary from node to node.

It will be appreciated that the other intermediate nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 within range will also be monitoring the transmission of packets by the first intermediate node B2 and the presence or absence of acknowledgements. In the same way as the calling node A, each of these intermediate nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 will eventually conclude that intermediate node B2 is faulty and will not route packets through that node.

If the sink node is the second or third intermediate node C3 or D3, then the calling node A will still fail to receive an acknowledgement and will re-transmit the packet, noting the possibility that the first intermediate node B2 is faulty. At the same time, of course, first intermediate node B2 and the second and third intermediate nodes C3,D3 will be monitoring each other and may, where there are a plurality of calling nodes, be transmitting other packets and failing to receive acknowledgements. If the sink node is the second intermediate node C3, it is possible, therefore, that the first intermediate node B2 will have identified the second intermediate node C3 as a sink node before the calling node A re-transmits the packet. In that case, the first intermediate node B2 will transmit the packet via a different intermediate node, such as the intermediate node C2, and so the calling node A will receive an acknowledgement.

If that identification has not been made before the packet is re-transmitted, there is a possibility, because the choice of nodes is made on an ad hoc basis, that the packet

will not be routed through the second intermediate node C3 but that the packet will take another route that results in the receipt of an acknowledgement. If, however, the packet is still routed through the second intermediate node C3, both the calling node A and the first intermediate node B2 will fail to receive acknowledgements. This will continue either until the ad hoc nature of the connections by-passes the second intermediate node C3 or until, as described above, the first intermediate node B2 has received a sufficient number of non-acknowledgements from the second intermediate node C3, whether arising from packets transmitted to it by the first intermediate node B2 or from other intermediate nodes B1,B3,C1,C2,C3,D1,D2,D3, to be sure that the second intermediate node C3 is a sink node. The first intermediate node B2, and the other intermediate nodes B1,B3,C1,C2,C3,D1,D2,D3, will then route packets avoiding the second intermediate node C3.

It will be appreciated that an intermediate node B1,B2,B3,C1,C2,C3,D1,D2,D3 may be a sink node either due to equipment failure or because the node B1,B2,B3,C1,C2,C3,D1,D2,D3 has been tampered with to cause the node B1,B2,B3,C1,C2,C3,D1,D2,D3 to be deliberately disruptive by producing false acknowledgements (e.g. by a virus). In this latter case, the use of the public/private key pair will ensure that such a faulty node is detected, because the false acknowledgement will not be able to replicate the signed acknowledgement from the network node E.

It will be appreciated that non-signed acknowledgements could be used and will detect nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 that are faulty through equipment failure but not nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 that are faulty through tampering to produce false acknowledgements. It will also be appreciated that the intermediate nodes B1,B2,B3,C1,C2,C3,D1,D2,D3 need not be fixed nodes, one or more of them could be mobile.

It will also be appreciated that a similar system could be employed for traffic in the reverse direction, i.e. between the network node E and the calling node A. Unless, however, the calling node A has the ability to produce a digital key signature algorithm, the acknowledgements produced by the calling node A will not be able to detect faulty intermediate nodes tampered with to produce false acknowledgements - although such nodes will be detected by traffic in the opposite direction between the calling node A to network node E.

It will be appreciated that the system will also operate to detect a sink node that transmits an availability signal, receives packets and transmits packets that are of unsatisfactory quality such that the destination node does not generate an acknowledgement signal on their receipt.

CLAIMS

1. A mobile radio network comprising an originating node, a destination node and a plurality of intermediate nodes, the originating node transmitting information to the destination node along a path including a succession of intermediate nodes in which each preceding node selects a succeeding intermediate node on the basis of an availability signal transmitted by the intermediate nodes, each intermediate node in the path transmitting an acknowledgement signal from the destination node to the originating node on receipt by the destination node of said information, each node monitoring the transmission of information and associated acknowledgement signals by the intermediate nodes and not selecting an available intermediate node if said node a predetermined number of times transmits information but does not transmit an associated acknowledgement signal.

2. A system according to claim 1 wherein each preceding intermediate node selects the succeeding intermediate node in the path by opportunistic relay so that there is a significant chance that successive paths between the originating node and the destination node will be different, a node not selecting an available intermediate node until there have been a sufficient number of transmissions of information and a corresponding number of non-transmissions of associated acknowledgement signals for the monitoring node to judge that the available node is the first node not to transmit an acknowledgement signal.

3. A system according to claim 2 wherein each node includes an algorithm for determining, from monitored transmissions of information from an intermediate node and non-transmissions of associated acknowledgement signals, whether to select the intermediate node.

4. A system according to claim 3 wherein the algorithm produces a signal not selecting an intermediate node on monitoring a predetermined number of successive transmissions of information and an associated successive non-transmission of acknowledgement signals from said intermediate node.

5. A system according to claim 3 wherein the algorithm produces a signal not selecting an intermediate node on monitoring n transmissions of information and m non-transmissions of acknowledgement signals associated with said n transmissions of information, where n>m, from said intermediate node.

6. A system according to any one of claims 1 to 5 wherein the acknowledgement signal produced by the destination mode is signed, each node receiving the acknowledgement signal verifying the signed acknowledgement signal and so determining whether the acknowledgement signal is genuine.

7. A system according to claim 6 wherein the destination node is a mobile switching centre, the acknowledgement signal being signed using a public key digital signature algorithm, the nodes other than the destination node holding the public key.

8. A system according to any one of claims 1 to 7 wherein the originating node is mobile.

9. A mobile radio system substantially as hereinbefore described with reference to the accompanying drawing.

Application No: GB 0017363.3
Claims searched: All

Examiner: Gareth Griffiths
Date of search: 24 January 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H4L LDGP, LRCMR, LRPTA)

Int Cl (Ed.7): H04L 12/28, 12/56

Other: Online Databases: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	WO98/17031 A2 (PHILIPS) p.14 line 16 - p.15 line 1	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.