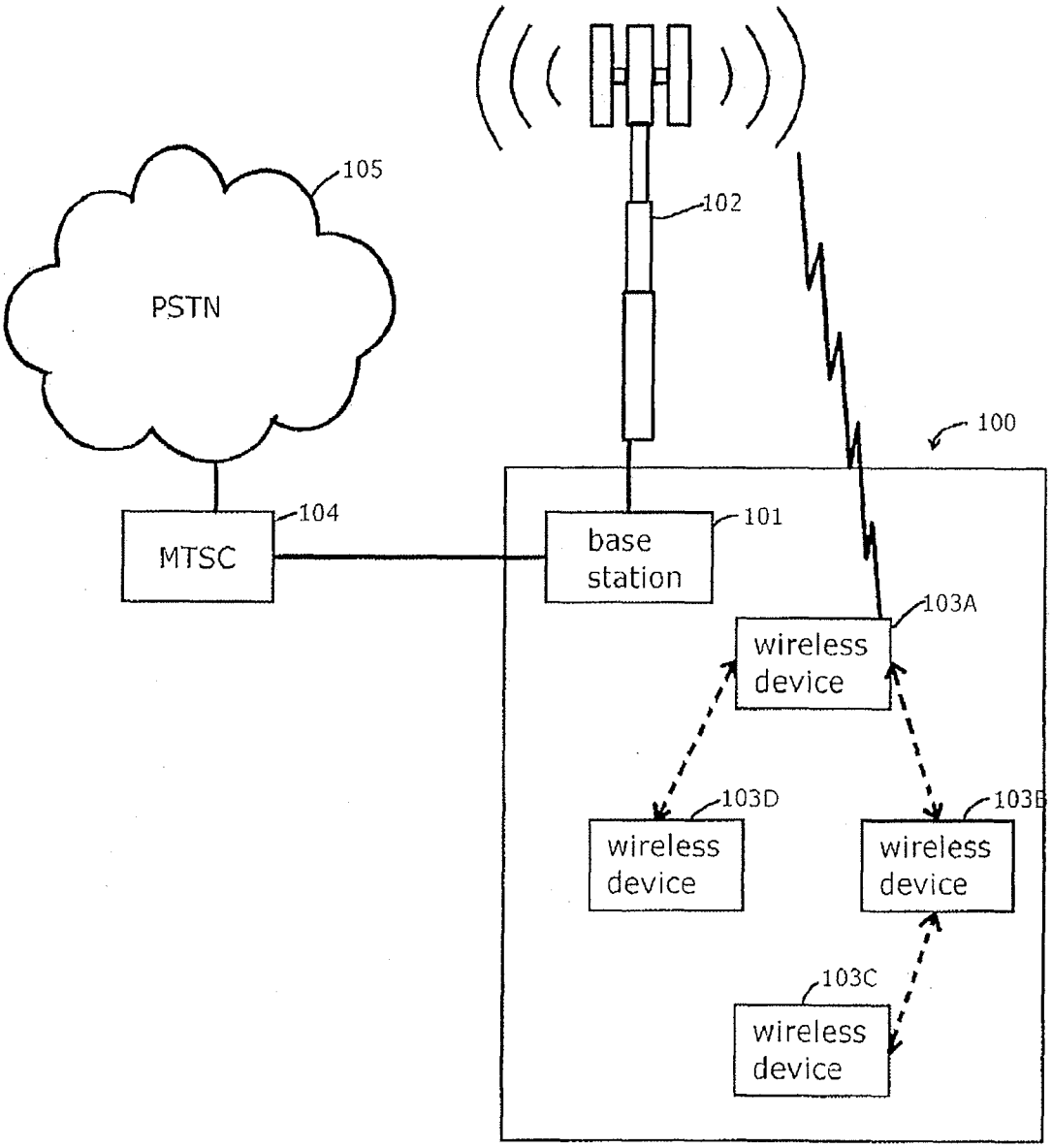

105
PSTN
102
100
104
MTSC
101
base station
103A
wireless device
103D
wireless device
103B
wireless device
103C
wireless device

Figure 1

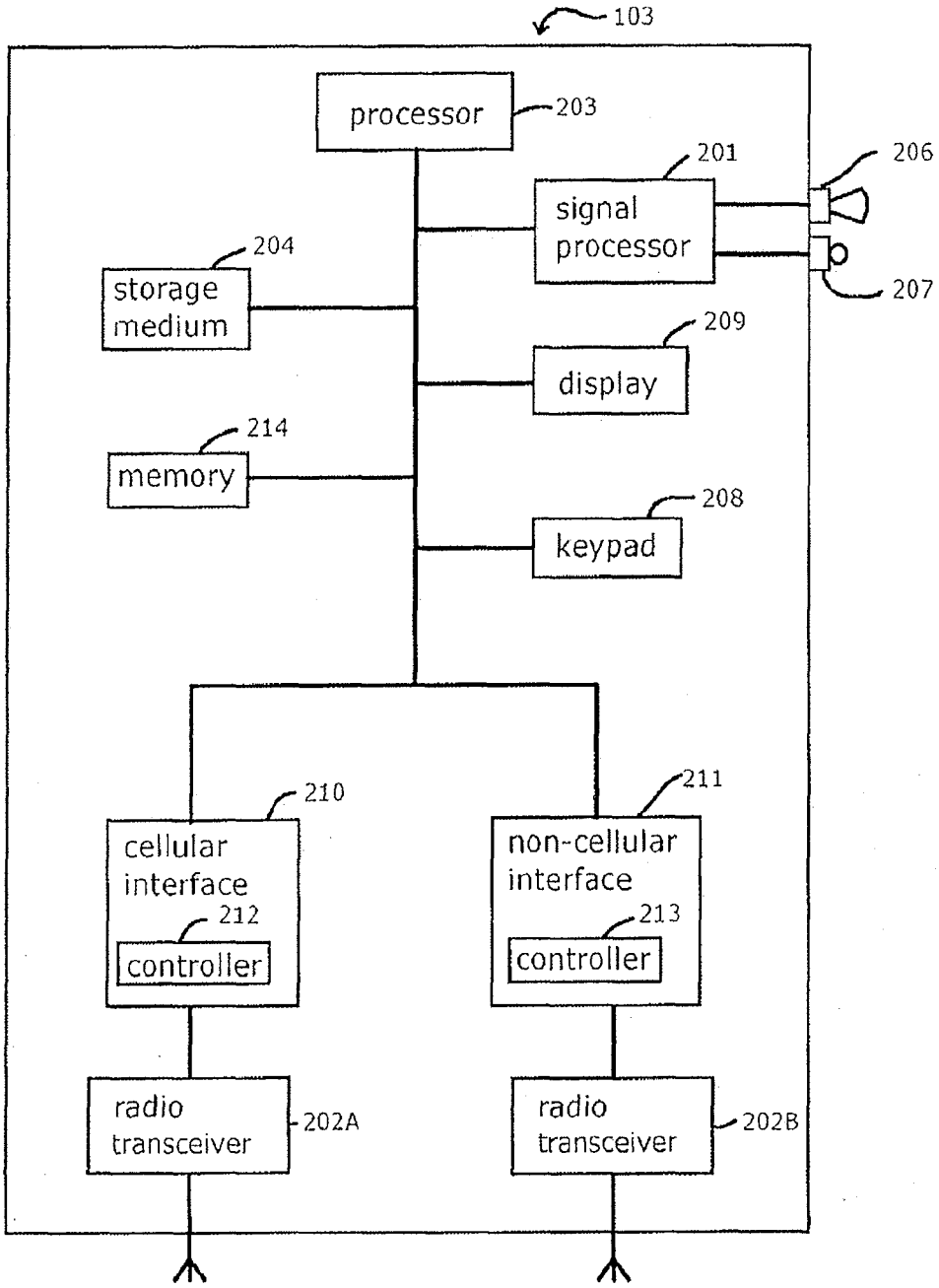

103
processor
203
201
206
signal processor
204
storage medium
207
209
display
214
memory
208
keypad
210
211
cellular interface
212
controller
non-cellular interface
213
controller
radio transceiver
202A
radio transceiver
202B

Figure 2

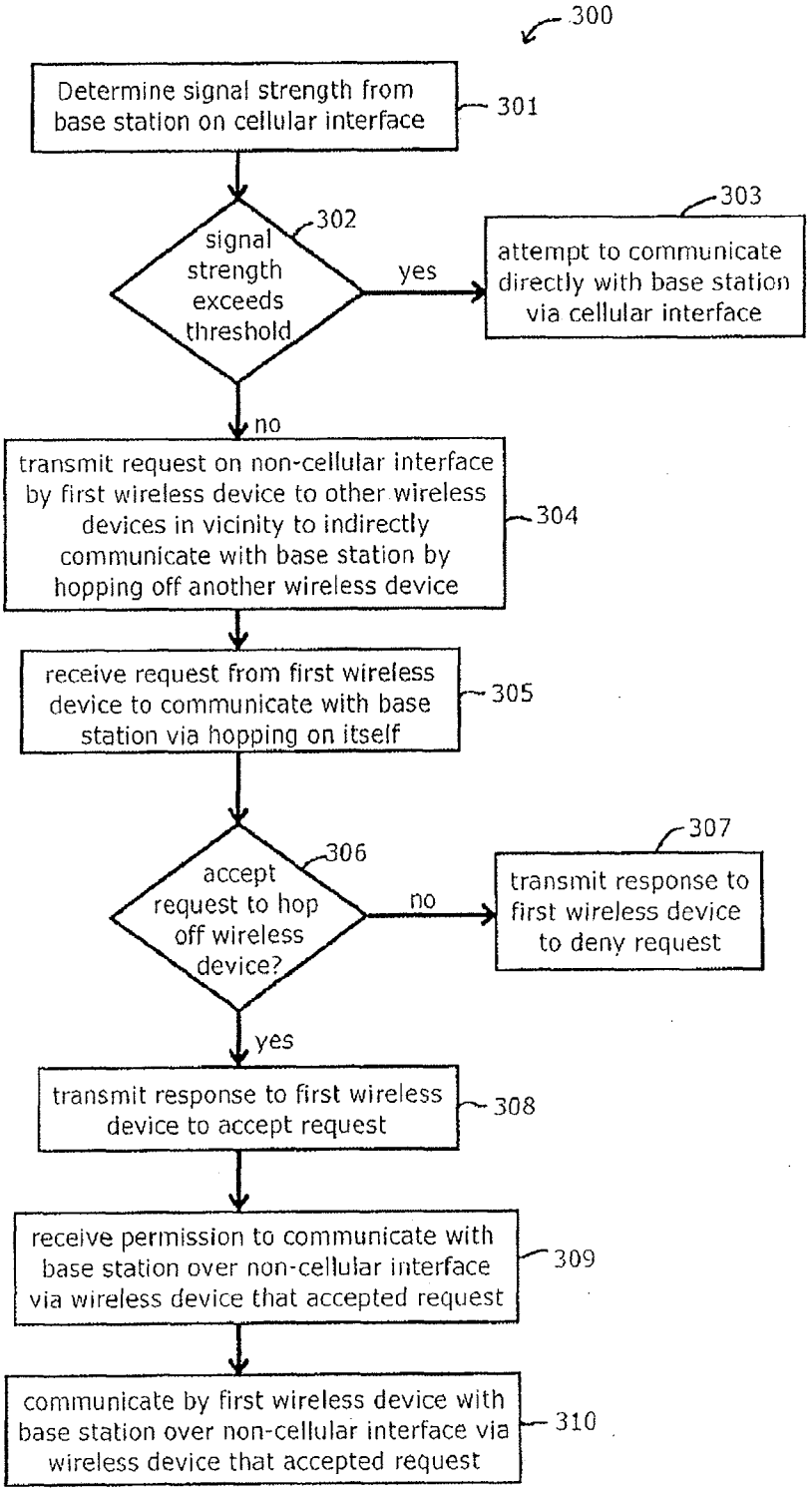

300
Determine signal strength from base station on cellular interface
301
signal strength exceeds threshold
302
yes
attempt to communicate directly with base station via cellular interface
303
no
transmit request on non-cellular interface by first wireless device to other wireless devices in vicinity to indirectly communicate with base station by hopping off another wireless device
304
receive request from first wireless device to communicate with base station via hopping on itself
305
accept request to hop off wireless device?
306
no
transmit response to first wireless device to deny request
307
yes
transmit response to first wireless device to accept request
308
receive permission to communicate with base station over non-cellular interface via wireless device that accepted request
309
communicate by first wireless device with base station over non-cellular interface via wireless device that accepted request
310

Figure 3

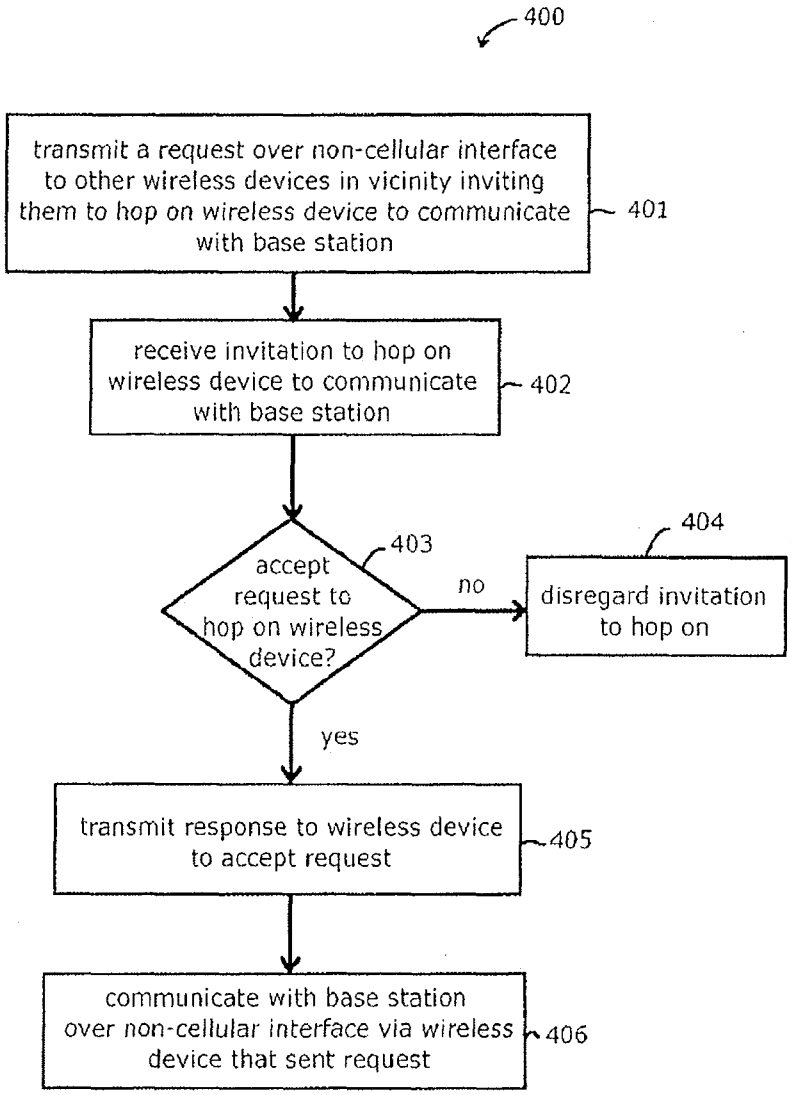

400
transmit a request over non-cellular interface to other wireless devices in vicinity inviting them to hop on wireless device to communicate with base station
401
receive invitation to hop on wireless device to communicate with base station
402
accept request to hop on wireless device?
403
no
disregard invitation to hop on
404
yes
transmit response to wireless device to accept request
405
communicate with base station over non-cellular interface via wireless device that sent request
406

Figure 4

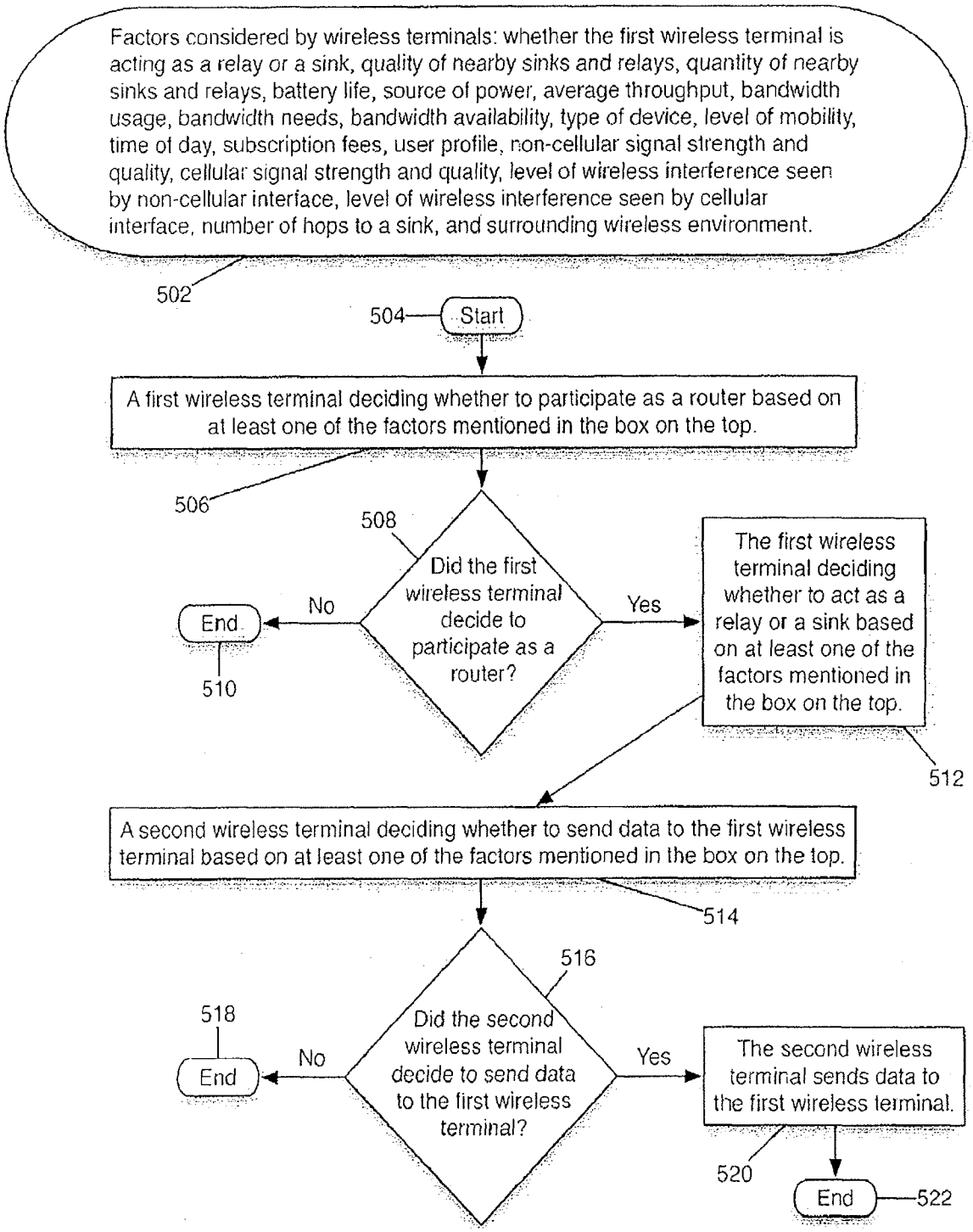

Factors considered by wireless terminals: whether the first wireless terminal is acting as a relay or a sink, quality of nearby sinks and relays, quantity of nearby sinks and relays, battery life, source of power, average throughput, bandwidth usage, bandwidth needs, bandwidth availability, type of device, level of mobility, time of day, subscription fees, user profile, non-cellular signal strength and quality, cellular signal strength and quality, level of wireless interference seen by non-cellular interface, level of wireless interference seen by cellular interface, number of hops to a sink, and surrounding wireless environment.
502
504
Start
A first wireless terminal deciding whether to participate as a router based on at least one of the factors mentioned in the box on the top.
506
508
Did the first wireless terminal decide to participate as a router?
No
End
510
Yes
The first wireless terminal deciding whether to act as a relay or a sink based on at least one of the factors mentioned in the box on the top.
512
A second wireless terminal deciding whether to send data to the first wireless terminal based on at least one of the factors mentioned in the box on the top.
514
516
Did the second wireless terminal decide to send data to the first wireless terminal?
518
No
End
Yes
The second wireless terminal sends data to the first wireless terminal.
520
End
522

Figure 5

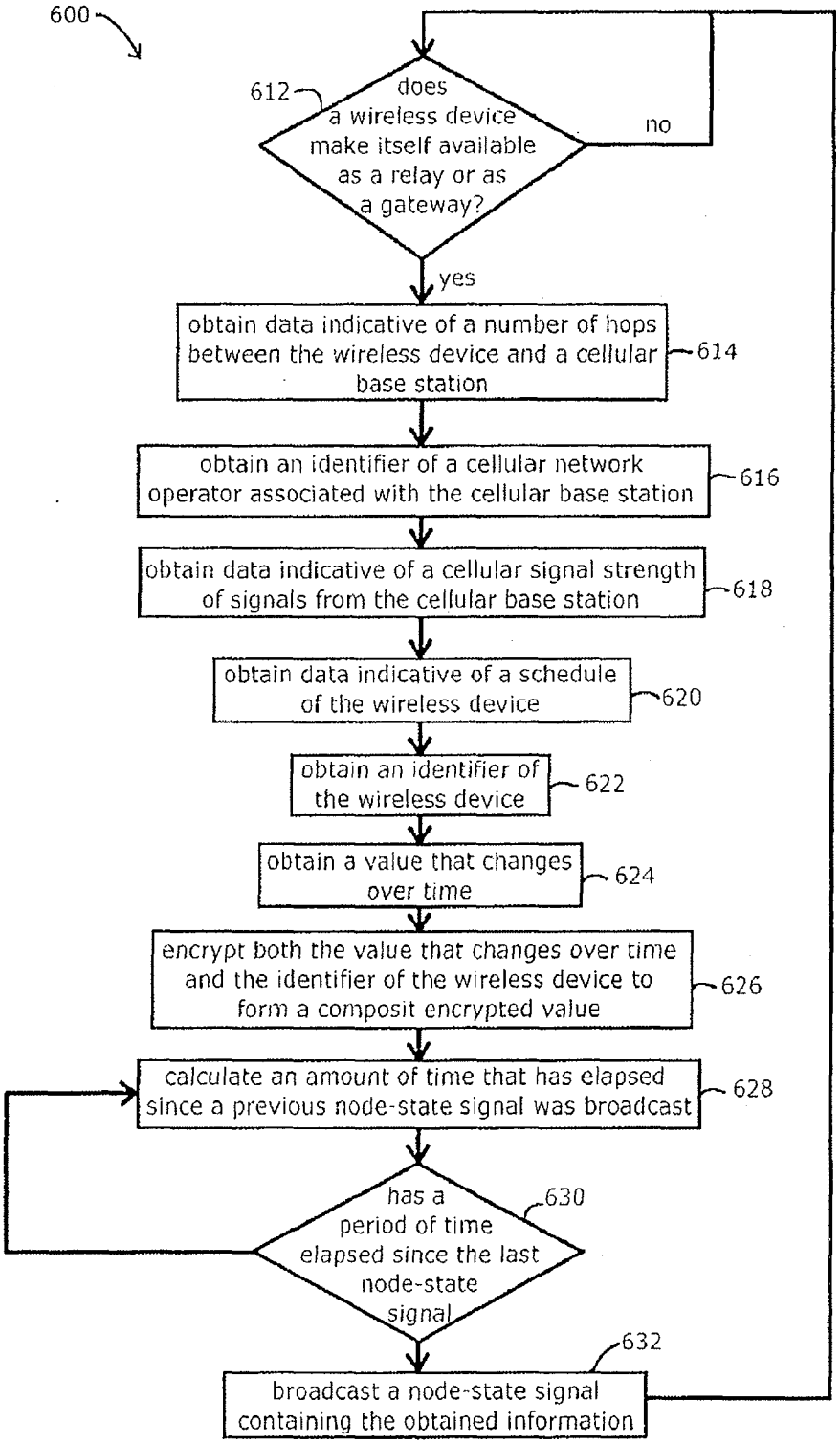

600
612
does a wireless device make itself available as a relay or as a gateway?
no
yes
obtain data indicative of a number of hops between the wireless device and a cellular base station
614
obtain an identifier of a cellular network operator associated with the cellular base station
616
obtain data indicative of a cellular signal strength of signals from the cellular base station
618
obtain data indicative of a schedule of the wireless device
620
obtain an identifier of the wireless device
622
obtain a value that changes over time
624
encrypt both the value that changes over time and the identifier of the wireless device to form a composit encrypted value
626
calculate an amount of time that has elapsed since a previous node-state signal was broadcast
628
has a period of time elapsed since the last node-state signal
630
broadcast a node-state signal containing the obtained information
632

Figure 6

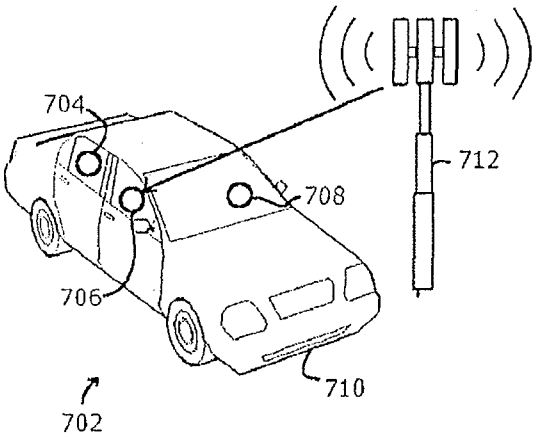


Figure 7A

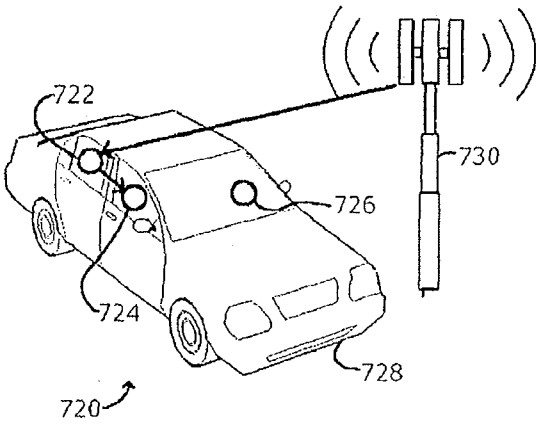


Figure 7B

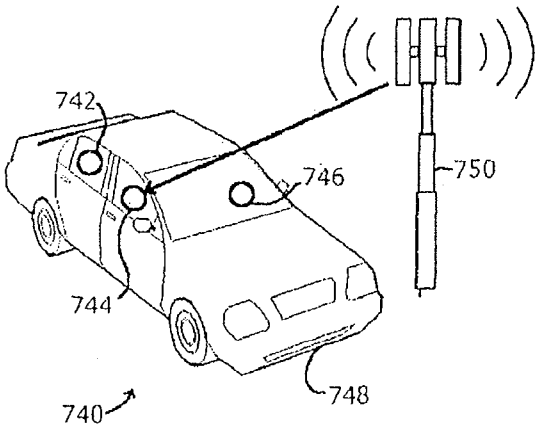


Figure 7C

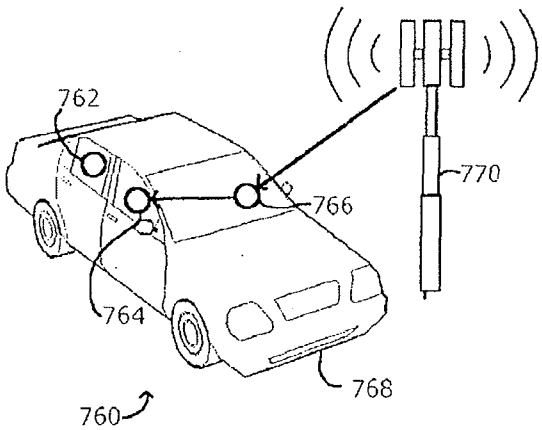


Figure 7D

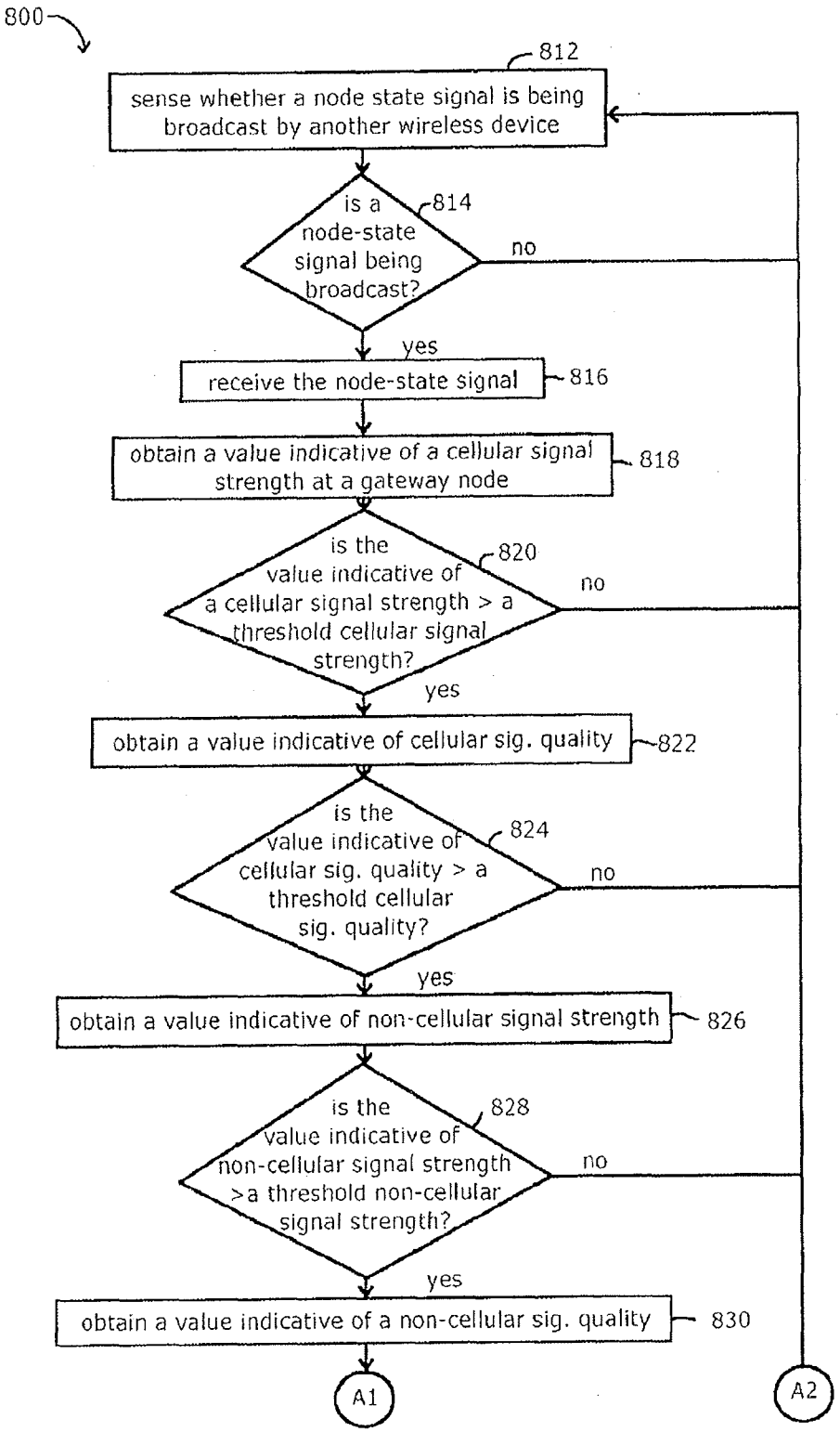

800
812
sense whether a node state signal is being broadcast by another wireless device
is a node-state signal being broadcast?
814
no
yes
receive the node-state signal
816
obtain a value indicative of a cellular signal strength at a gateway node
818
is the value indicative of a cellular signal strength > a threshold cellular signal strength?
820
no
yes
obtain a value indicative of cellular sig. quality
822
is the value indicative of cellular sig. quality > a threshold cellular sig. quality?
824
no
yes
obtain a value indicative of non-cellular signal strength
826
is the value indicative of non-cellular signal strength >a threshold non-cellular signal strength?
828
no
yes
obtain a value indicative of a non-cellular sig. quality
830
A1
A2

Figure 8A

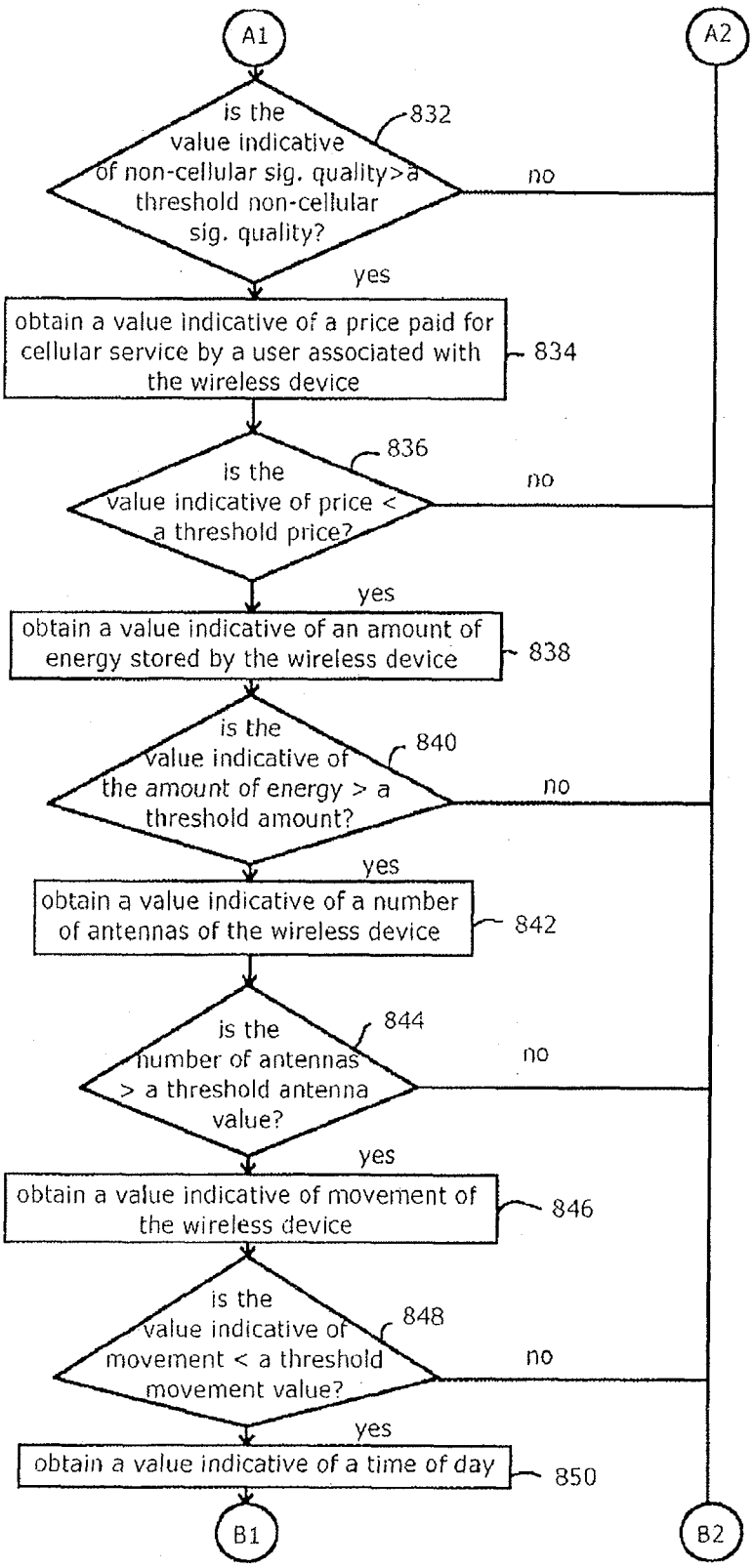

A1
A2
is the value indicative of non-cellular sig. quality>a threshold non-cellular sig. quality?
832
no
yes
obtain a value indicative of a price paid for cellular service by a user associated with the wireless device
834
is the value indicative of price < a threshold price?
836
no
yes
obtain a value indicative of an amount of energy stored by the wireless device
838
is the value indicative of the amount of energy > a threshold amount?
840
no
yes
obtain a value indicative of a number of antennas of the wireless device
842
is the number of antennas > a threshold antenna value?
844
no
yes
obtain a value indicative of movement of the wireless device
846
is the value indicative of movement < a threshold movement value?
848
no
yes
obtain a value indicative of a time of day
850
B1
B2

Figure 8B

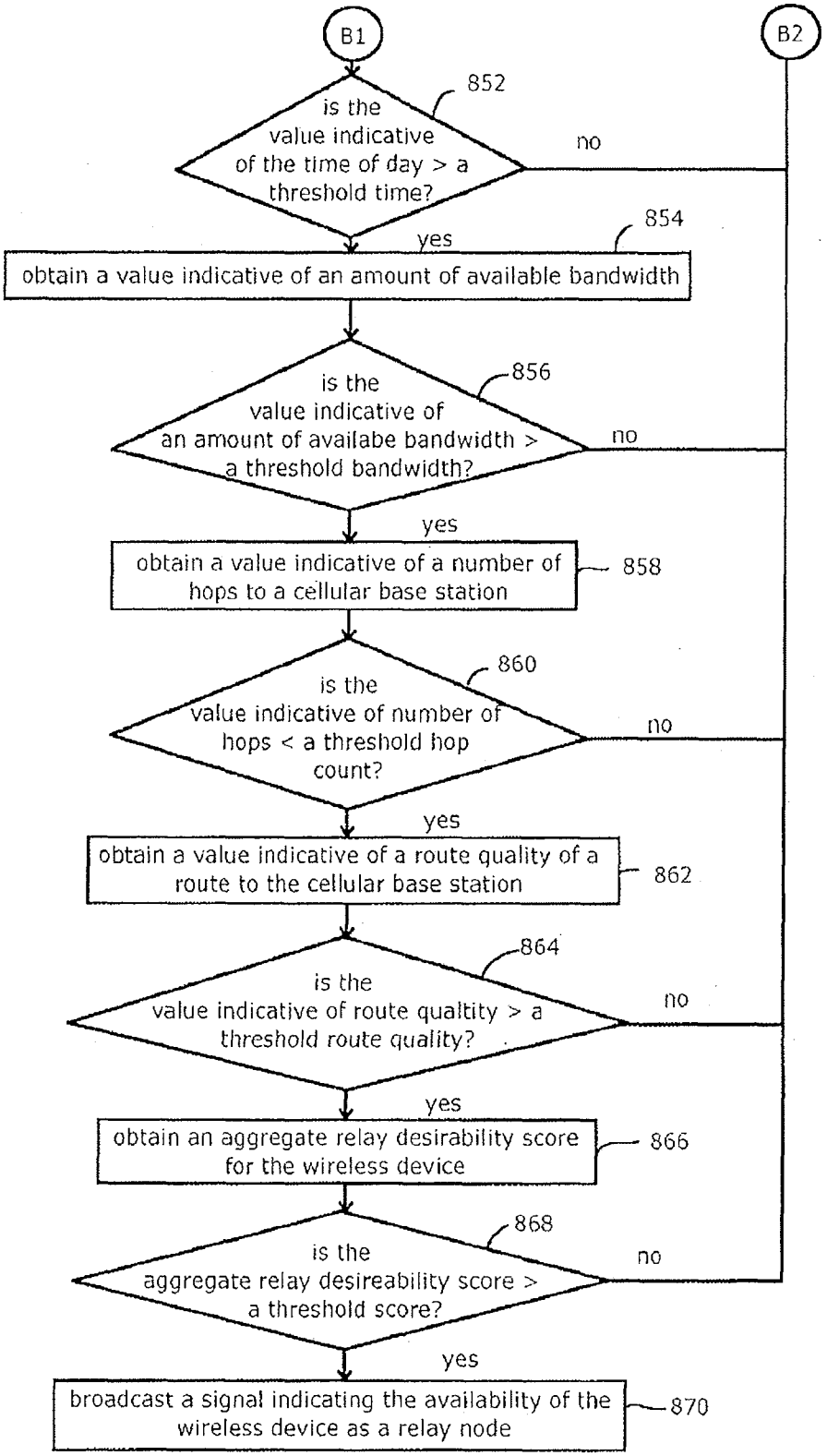

B1
B2
852
is the value indicative of the time of day > a threshold time?
no
yes
854
obtain a value indicative of an amount of available bandwidth
856
is the value indicative of an amount of availabe bandwidth > a threshold bandwidth?
no
yes
obtain a value indicative of a number of hops to a cellular base station
858
860
is the value indicative of number of hops < a threshold hop count?
no
yes
obtain a value indicative of a route quality of a route to the cellular base station
862
864
is the value indicative of route qualtity > a threshold route quality?
no
yes
obtain an aggregate relay desirability score for the wireless device
866
868
is the aggregate relay desireability score > a threshold score?
no
yes
broadcast a signal indicating the availability of the wireless device as a relay node
870

Figure 8C

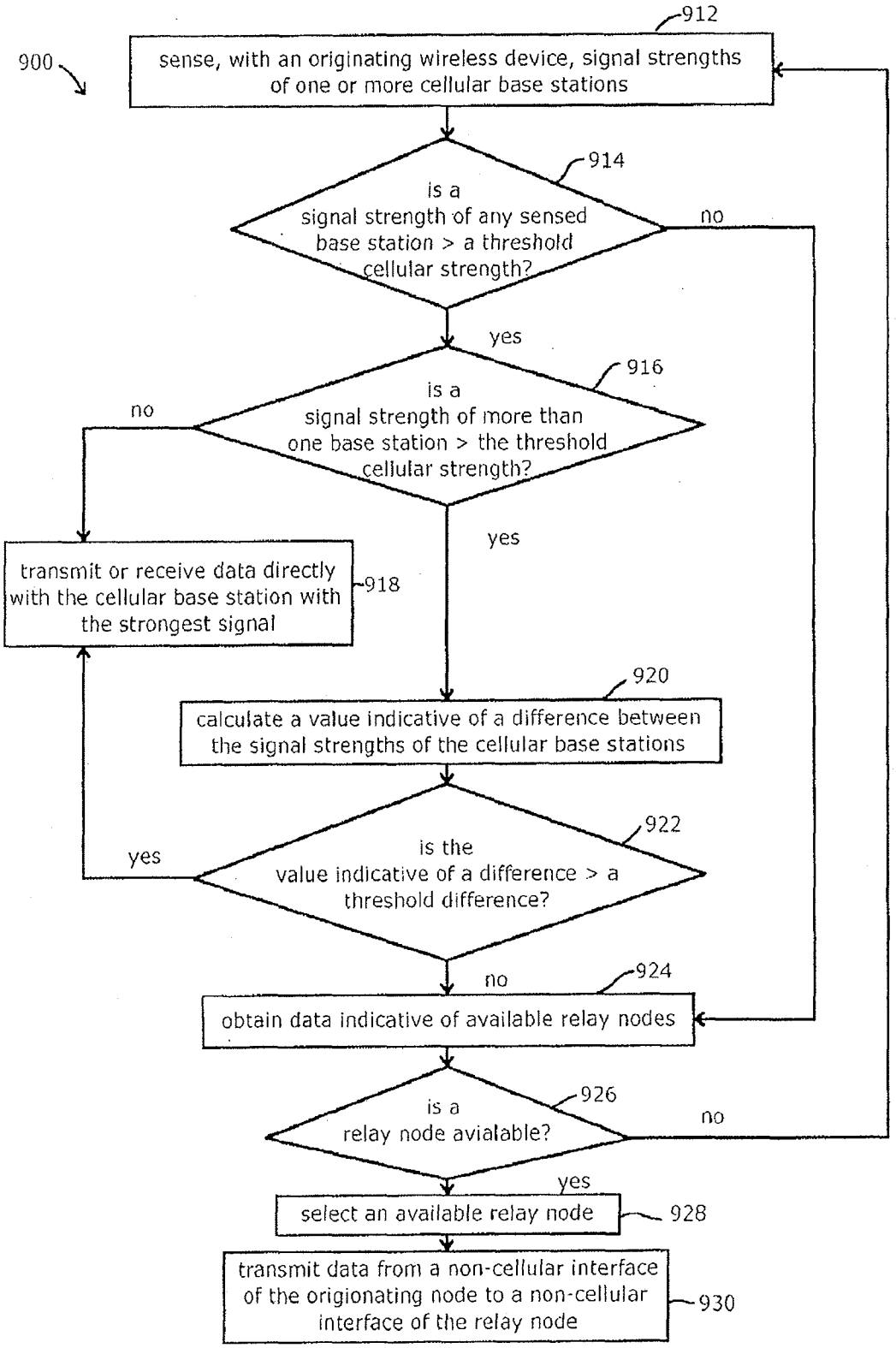

900
912
sense, with an originating wireless device, signal strengths of one or more cellular base stations
914
is a signal strength of any sensed base station > a threshold cellular strength?
no
yes
916
is a signal strength of more than one base station > the threshold cellular strength?
no
yes
transmit or receive data directly with the cellular base station with the strongest signal
918
920
calculate a value indicative of a difference between the signal strengths of the cellular base stations
922
is the value indicative of a difference > a threshold difference?
yes
no
924
obtain data indicative of available relay nodes
926
is a relay node avialable?
no
yes
select an available relay node
928
transmit data from a non-cellular interface of the origionating node to a non-cellular interface of the relay node
930

Figure 9

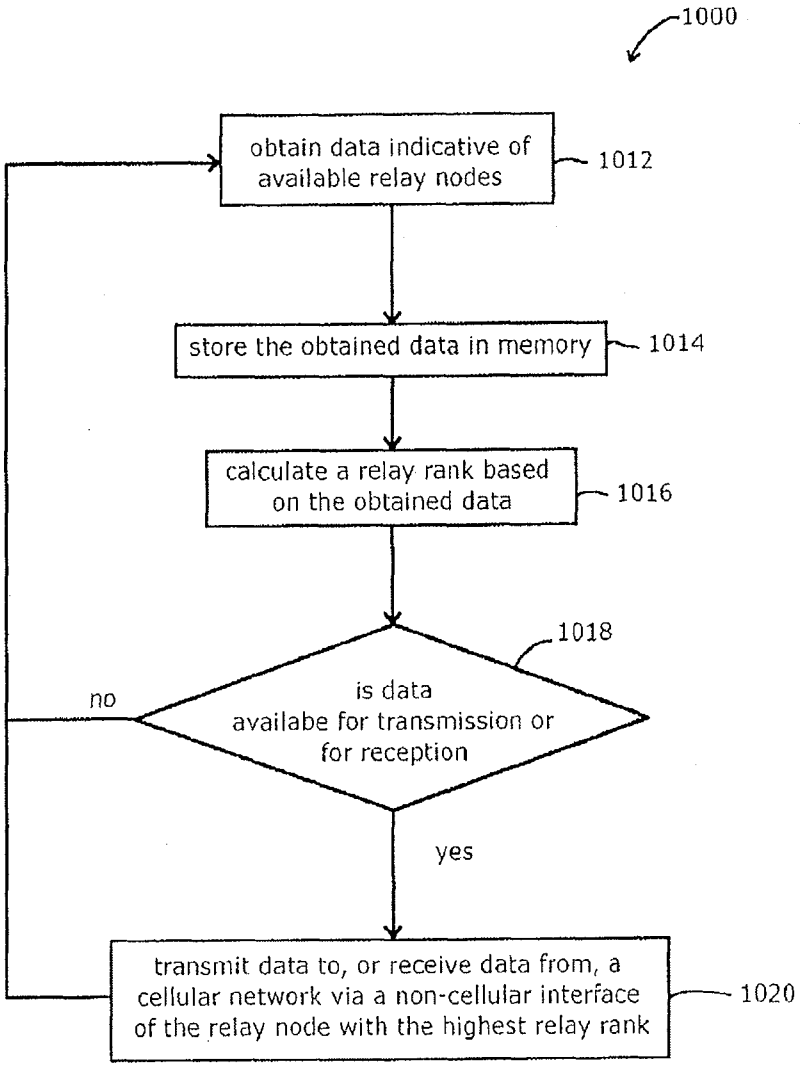

1000
obtain data indicative of available relay nodes
1012
store the obtained data in memory
1014
calculate a relay rank based on the obtained data
1016
1018
is data availabe for transmission or for reception
no
yes
transmit data to, or receive data from, a cellular network via a non-cellular interface of the relay node with the highest relay rank
1020

Figure 10

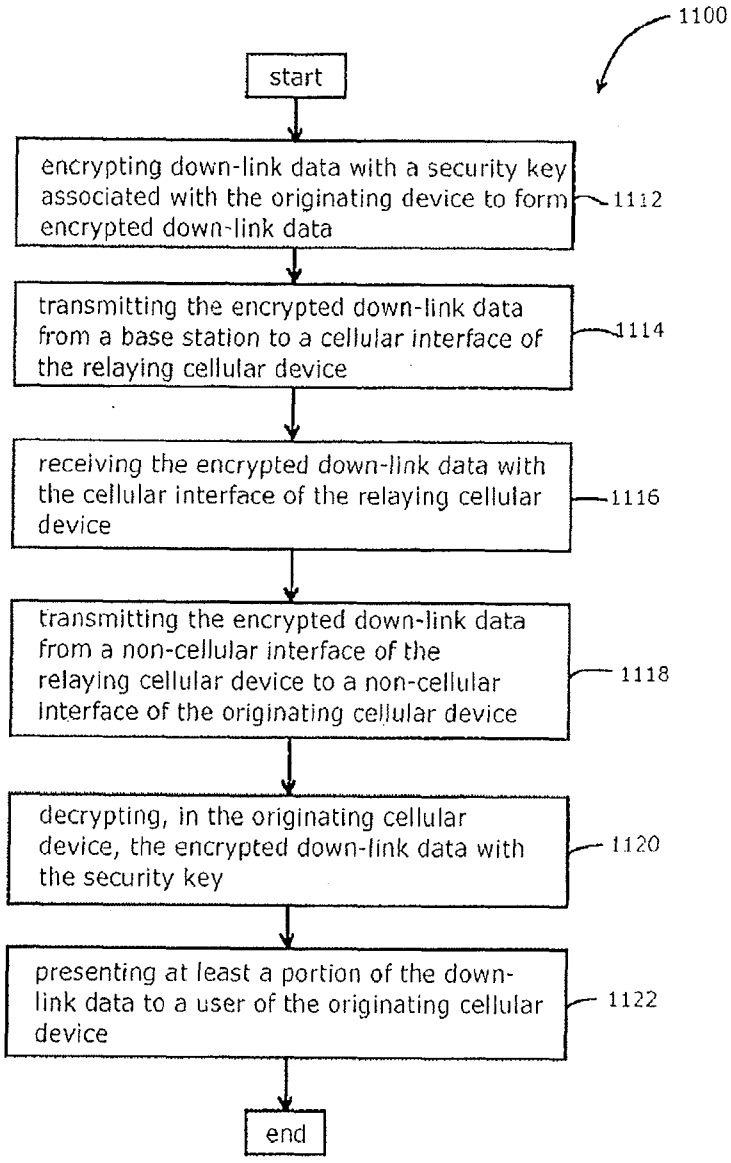

1100
start
encrypting down-link data with a security key associated with the originating device to form encrypted down-link data
1112
transmitting the encrypted down-link data from a base station to a cellular interface of the relaying cellular device
1114
receiving the encrypted down-link data with the cellular interface of the relaying cellular device
1116
transmitting the encrypted down-link data from a non-cellular interface of the relaying cellular device to a non-cellular interface of the originating cellular device
1118
decrypting, in the originating cellular device, the encrypted down-link data with the security key
1120
presenting at least a portion of the down-link data to a user of the originating cellular device
1122
end

Figure 11

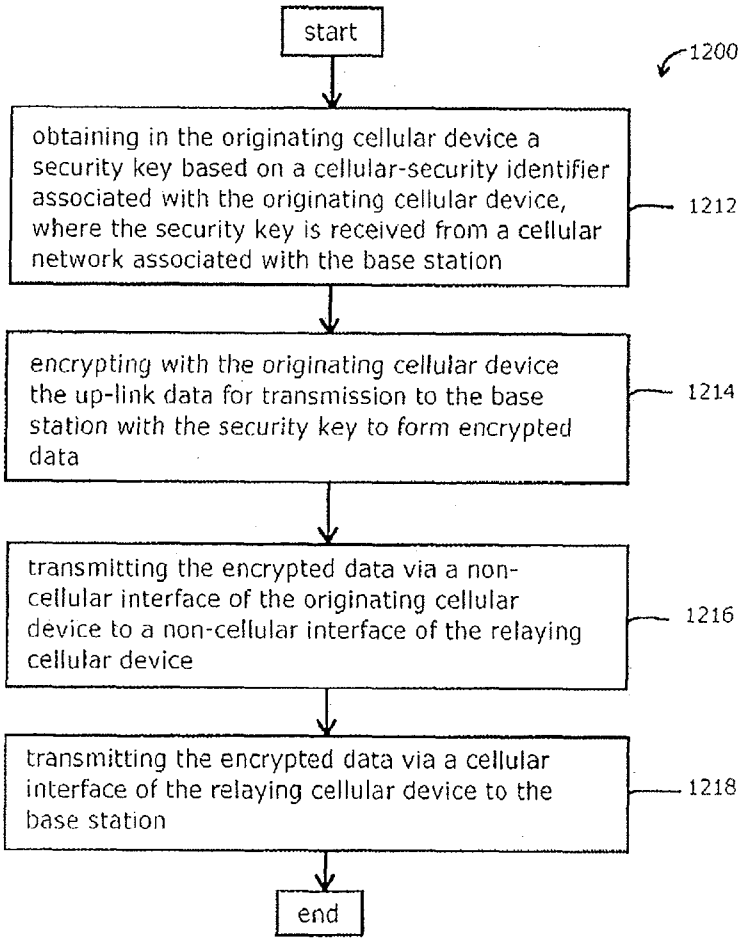

start
1200
obtaining in the originating cellular device a security key based on a cellular-security identifier associated with the originating cellular device, where the security key is received from a cellular network associated with the base station
1212
encrypting with the originating cellular device the up-link data for transmission to the base station with the security key to form encrypted data
1214
transmitting the encrypted data via a non-cellular interface of the originating cellular device to a non-cellular interface of the relaying cellular device
1216
transmitting the encrypted data via a cellular interface of the relaying cellular device to the base station
1218
end

Figure 12

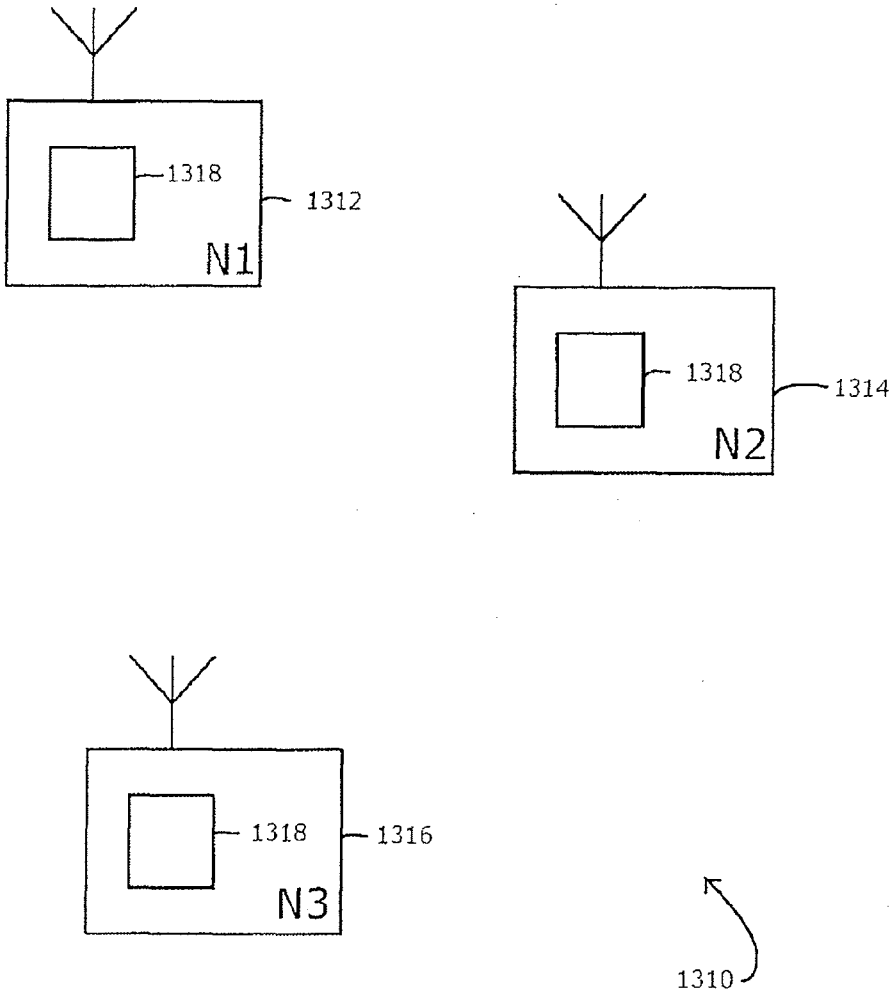


Figure 13

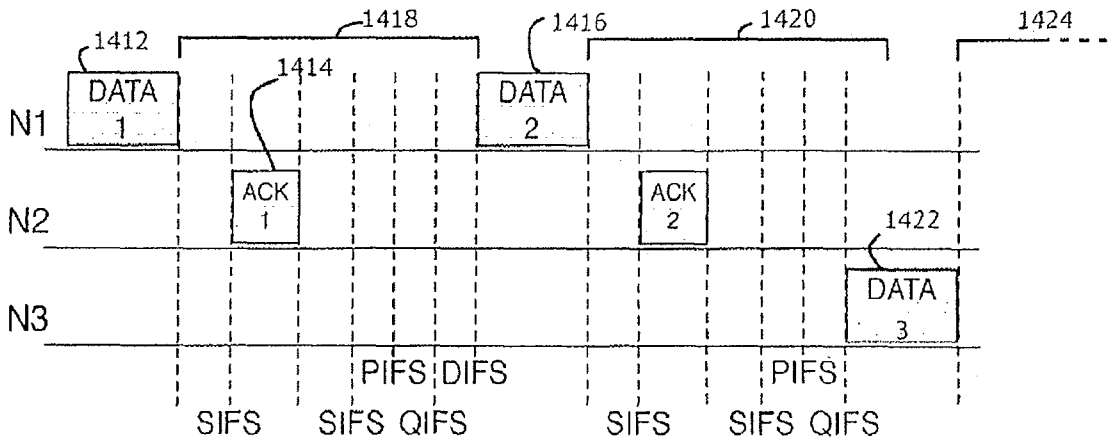


Figure 14

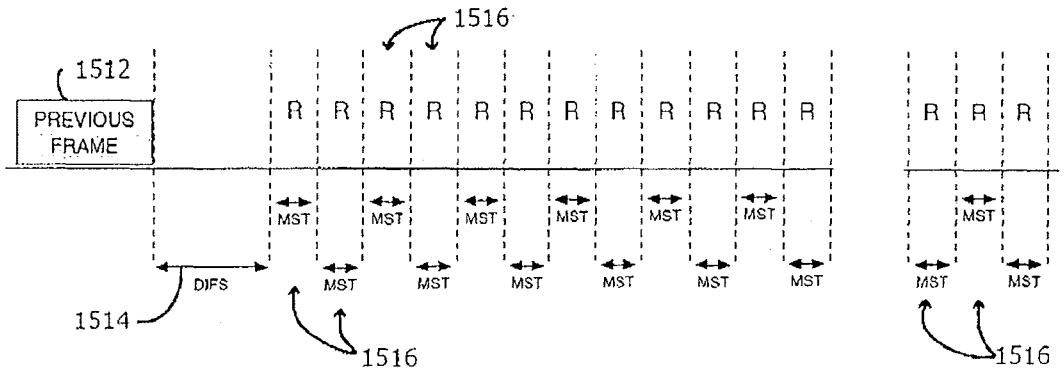


Figure 15

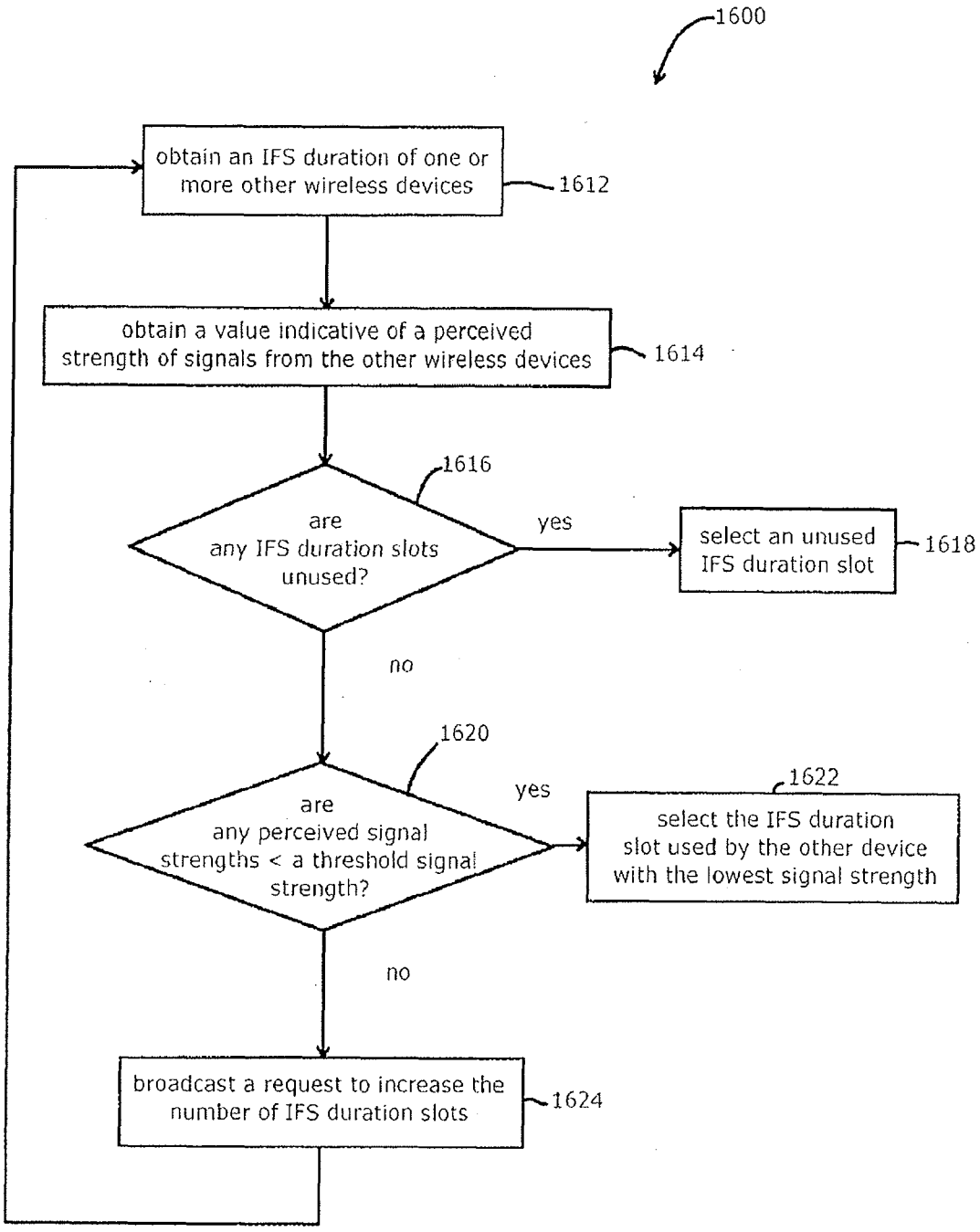

1600
obtain an IFS duration of one or more other wireless devices
1612
obtain a value indicative of a perceived strength of signals from the other wireless devices
1614
1616
are any IFS duration slots unused?
yes
select an unused IFS duration slot
1618
no
1620
are any perceived signal strengths < a threshold signal strength?
yes
1622
select the IFS duration slot used by the other device with the lowest signal strength
no
broadcast a request to increase the number of IFS duration slots
1624

Figure 16

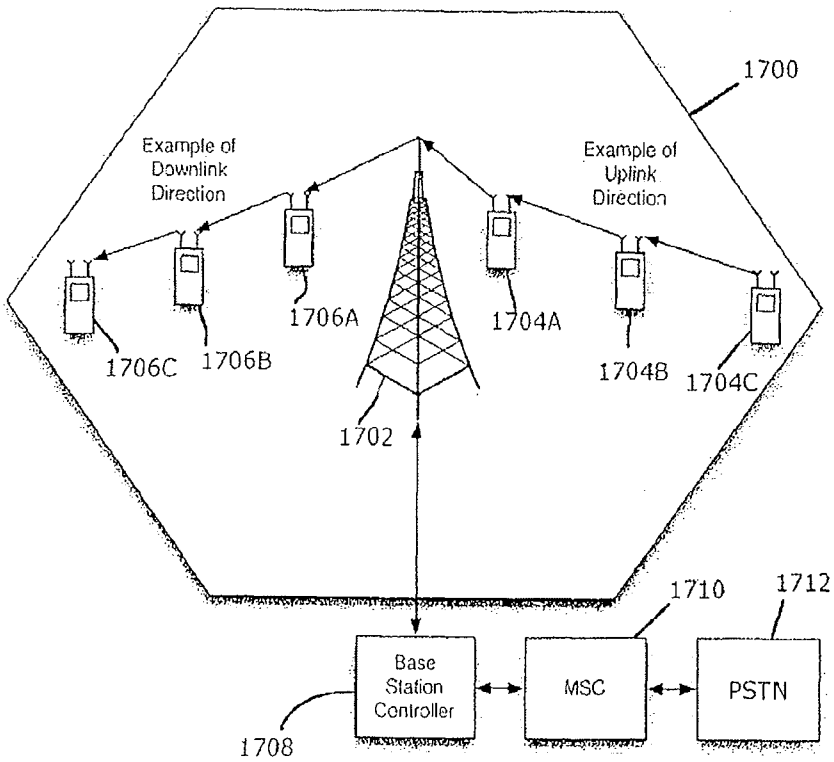

1700
Example of Downlink Direction
Example of Uplink Direction
1706A
1704A
1706C
1706B
1704B
1704C
1702
1710
1712
Base Station Controller
MSC
PSTN
1708

Figure 17

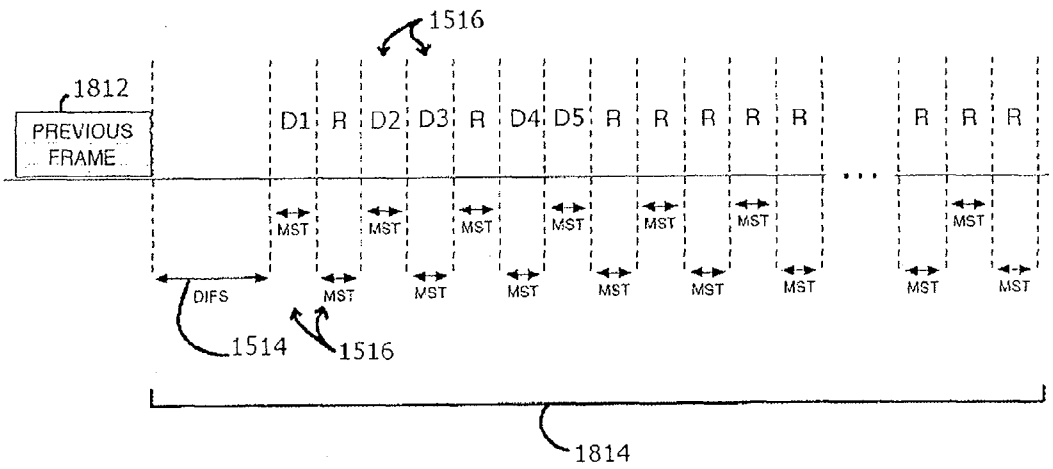

1516
1812
PREVIOUS FRAME
D1
R
D2
D3
R
D4
D5
R
R
R
R
R
R
R
R
MST
DIFS
1514
1516
1814

Figure 18

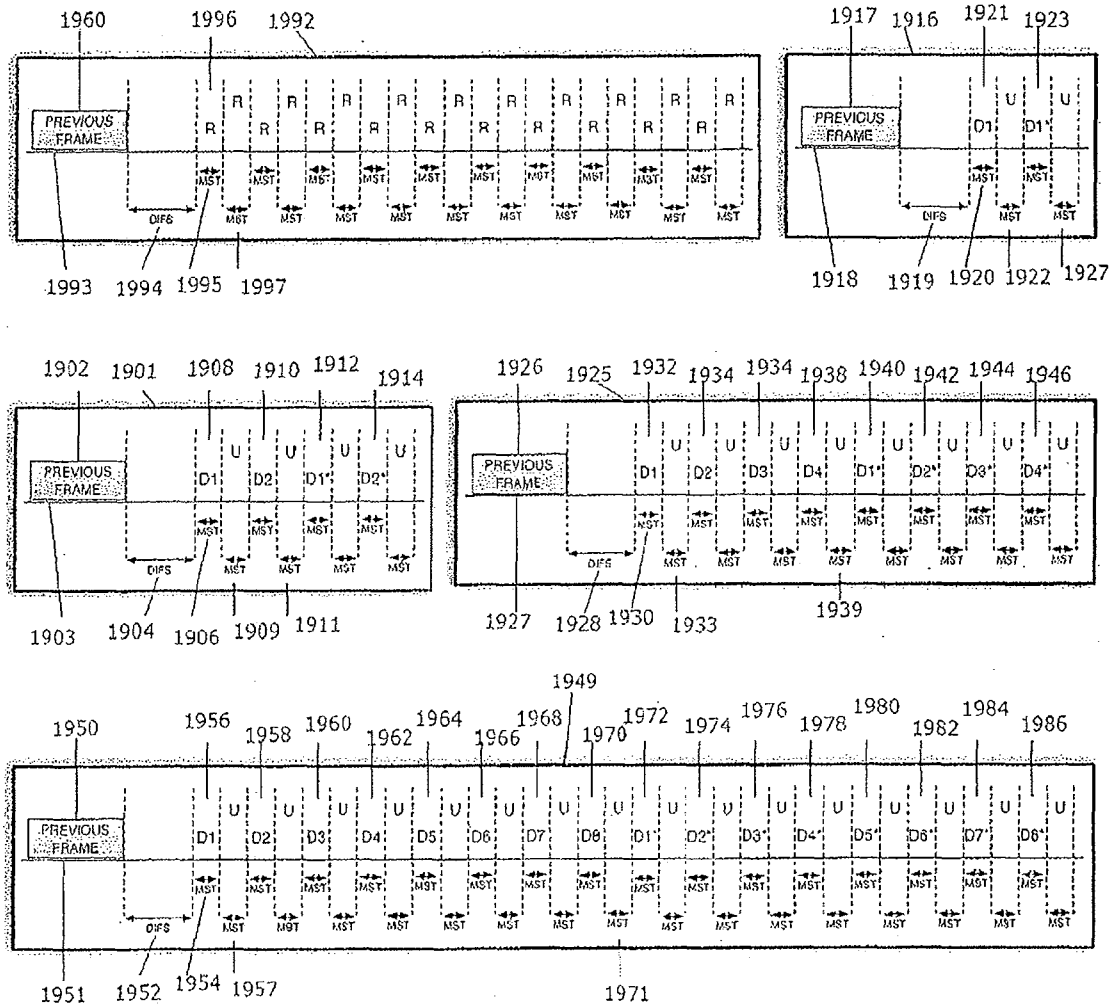

1960
1996
1992
PREVIOUS FRAME
R
MST
DIFS
1993
1994
1995
1997
1917
1916
1921
1923
D1
D1'
U
1918
1919
1920
1922
1927
1902
1901
1908
1910
1912
1914
D2
D2'
1903
1904
1906
1909
1911
1926
1925
1932
1934
1938
1940
1942
1944
1946
D3
D4
D3'
D4'
1927
1928
1930
1933
1939
1949
1950
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
D5
D6
D7
D8
D5'
D6'
D7'
D8'
1951
1952
1954
1957
1971

Figure 19

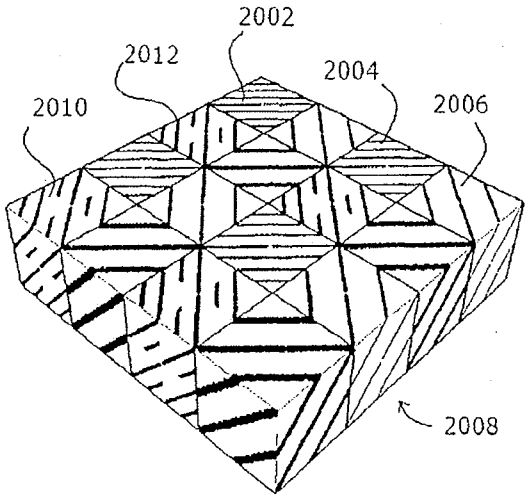


Figure 20A

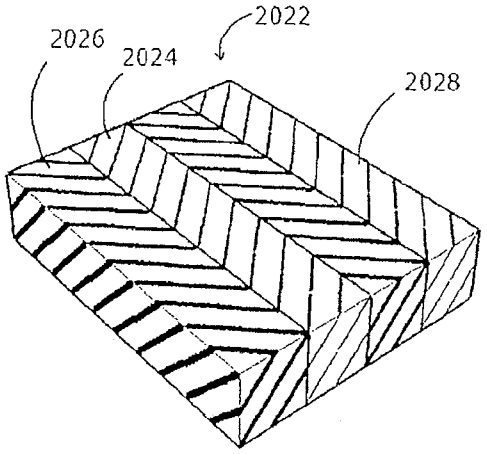


Figure 20B

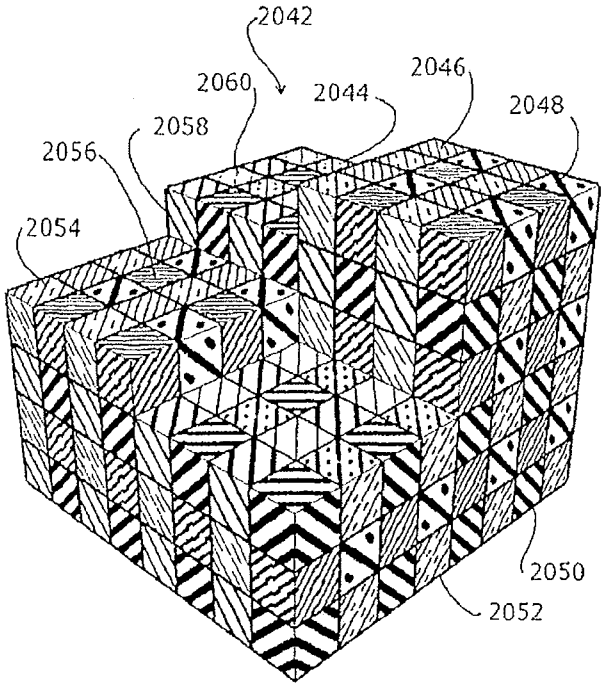


Figure 20C

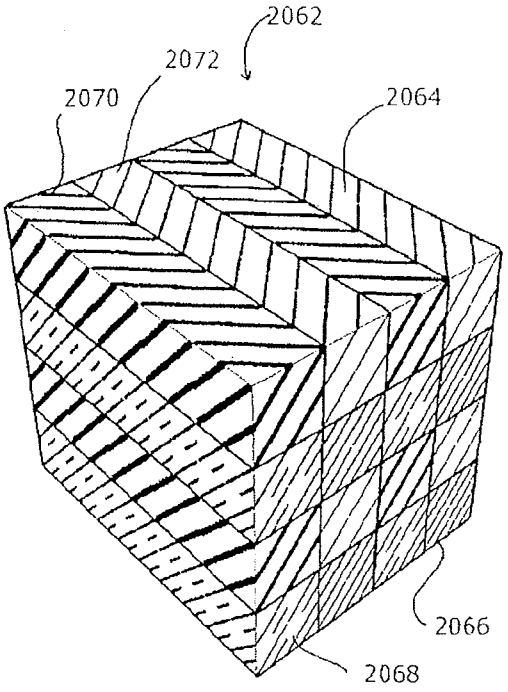
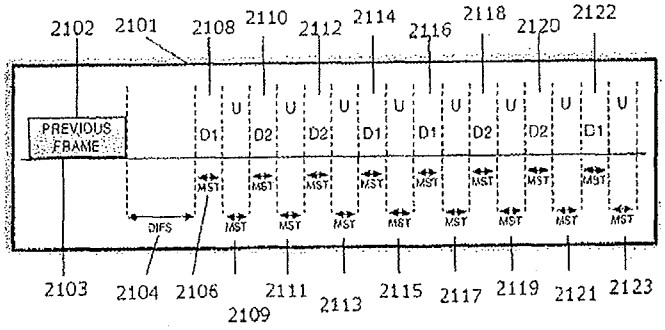
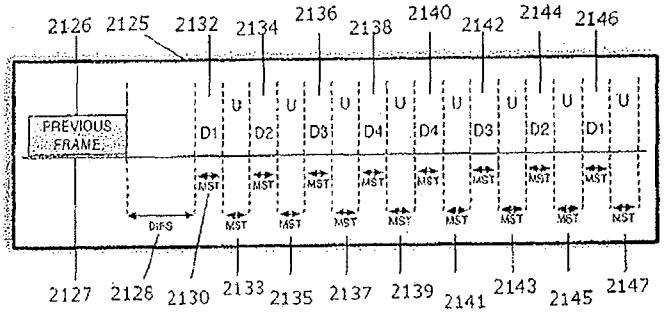


Figure 20D





2149

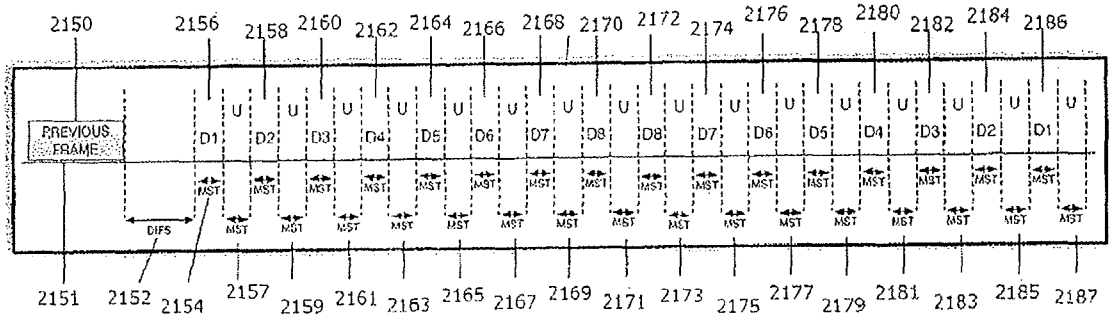
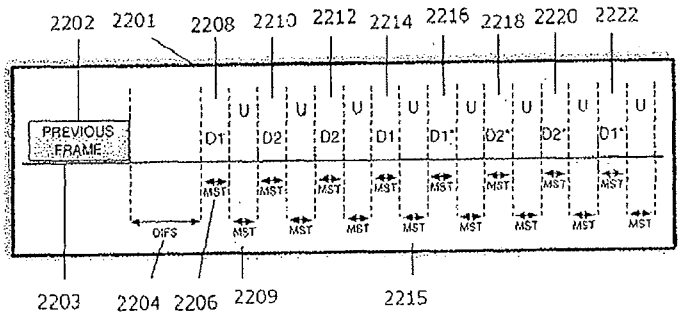
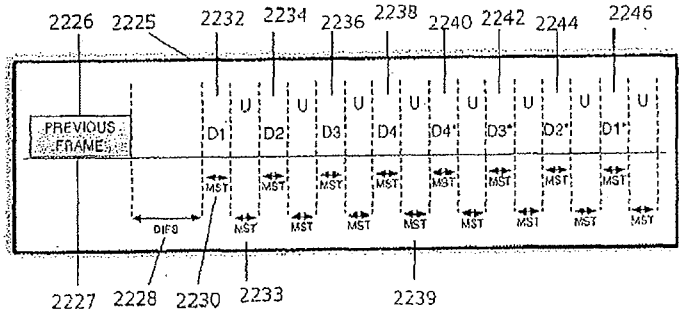


Figure 21


2202
2201
2208
2210
2212
2214
2216
2218
2220
2222
PREVIOUS FRAME
D1
D2
D2
D1
D1'
D2'
D2'
D1'
U
MST
DIFS
2203
2204
2206
2209
2215


2226
2225
2232
2234
2236
2238
2240
2242
2244
2246
PREVIOUS FRAME
D1
D2
D3
D4
D4'
D3'
D2'
D1'
U
MST
DIFS
2227
2228
2230
2233
2239

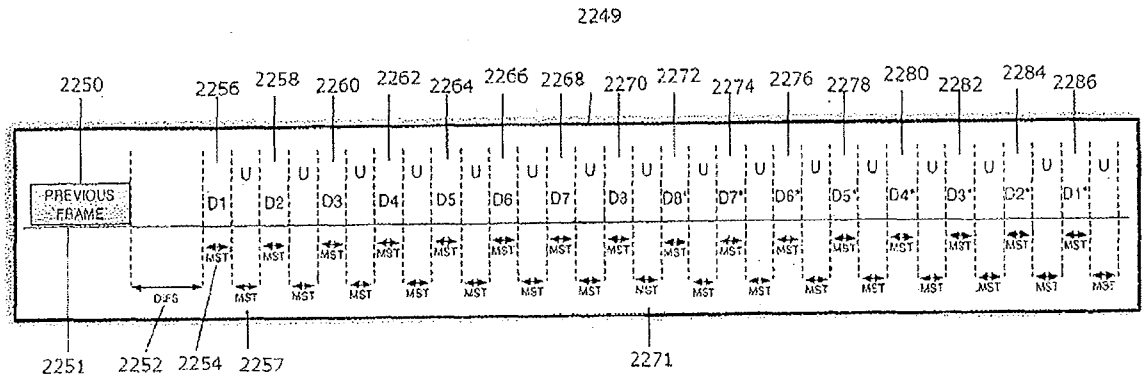
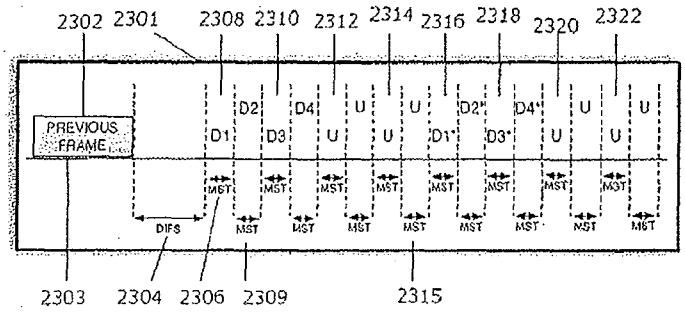
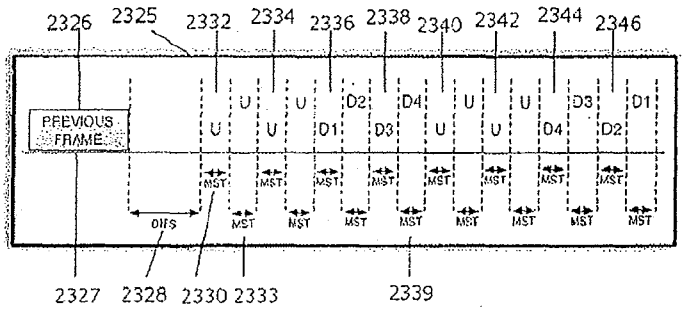

2249
2250
2256
2258
2260
2262
2264
2266
2268
2270
2272
2274
2276
2278
2280
2282
2284
2286
PREVIOUS FRAME
D1
D2
D3
D4
D5
D6
D7
D3
D8'
D7'
D6'
D5'
D4'
D3'
D2'
D1'
U
MST
DIFS
2251
2252
2254
2257
2271

Figure 22





2349

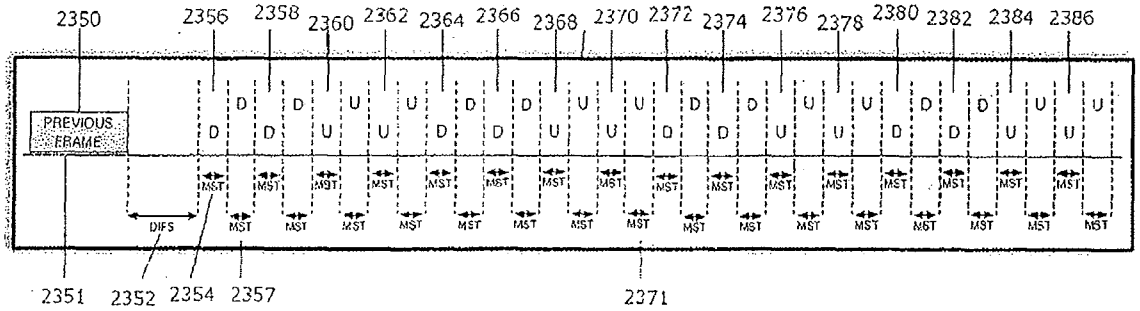


Figure 23

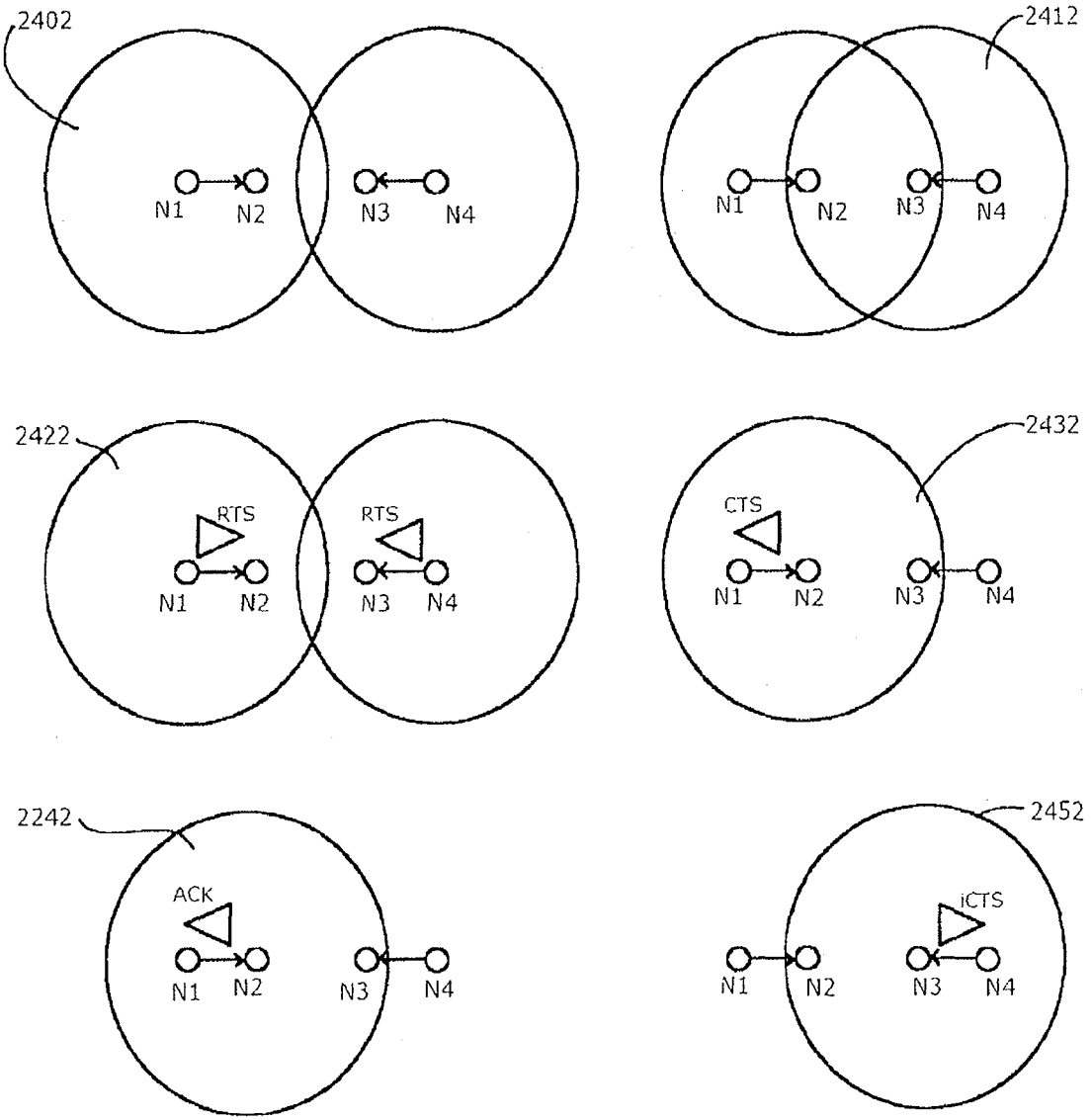

2402
N1
N2
N3
N4
2412
N1
N2
N3
N4
2422
RTS
RTS
N1
N2
N3
N4
2432
CTS
N1
N2
N3
N4
2242
ACK
N1
N2
N3
N4
2452
iCTS
N1
N2
N3
N4

Figure 24

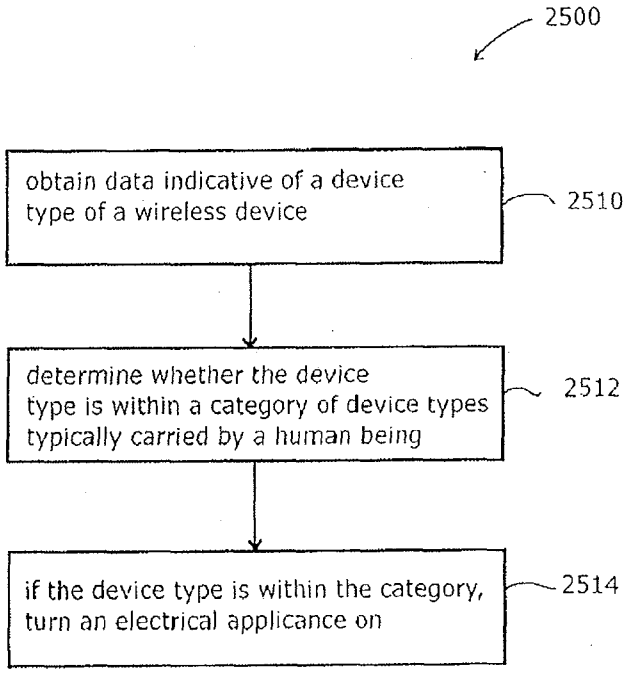


Figure 25A

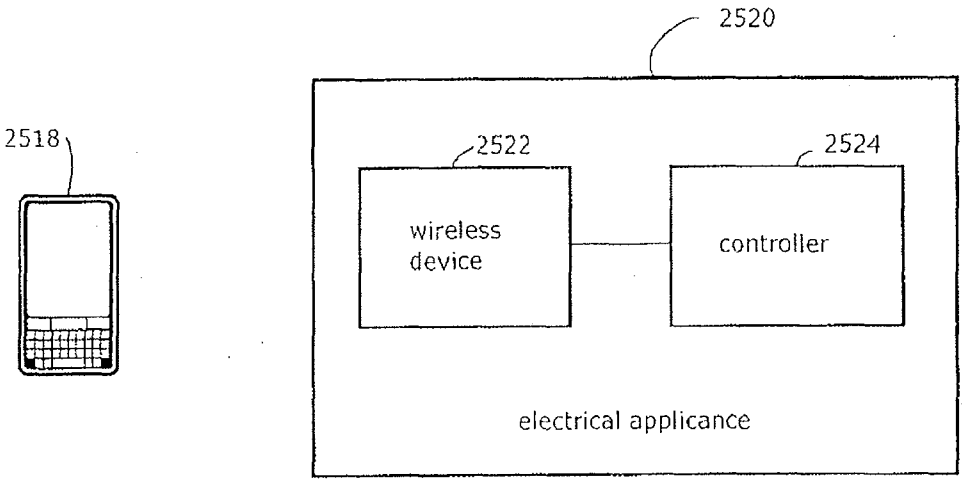


Figure 25B

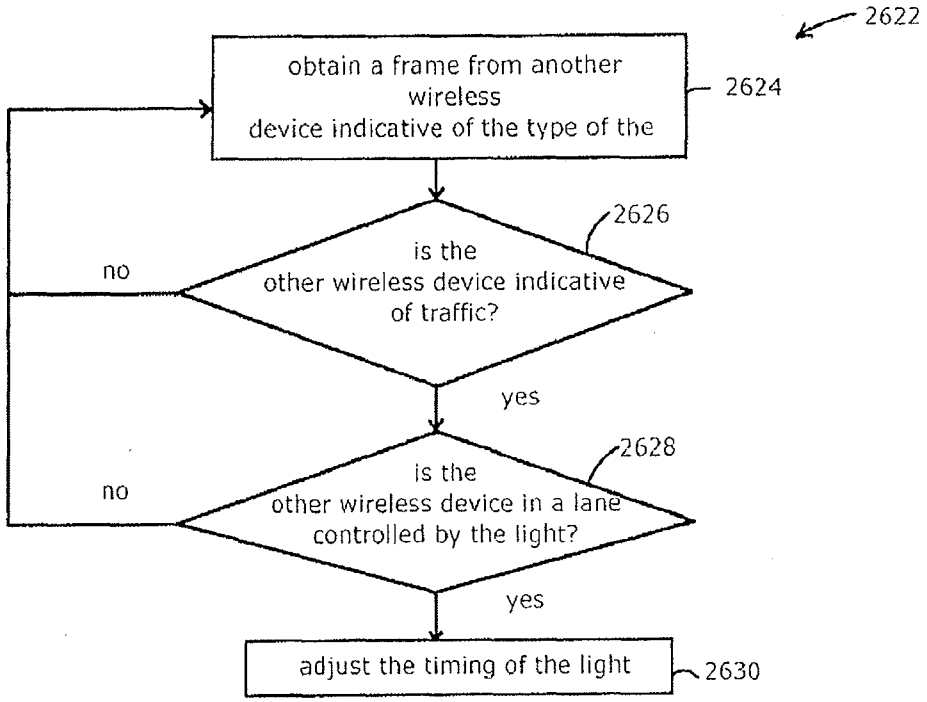


Figure 26A

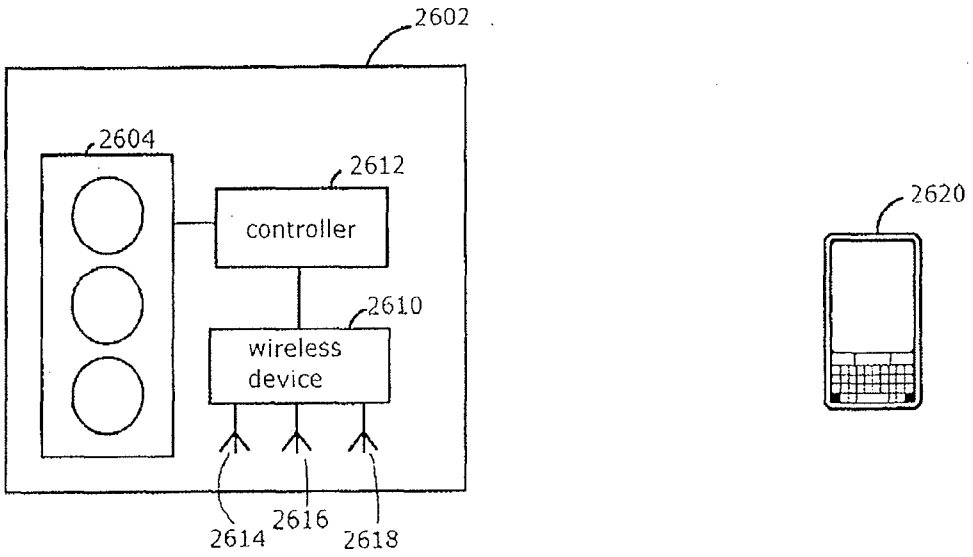


Figure 26B

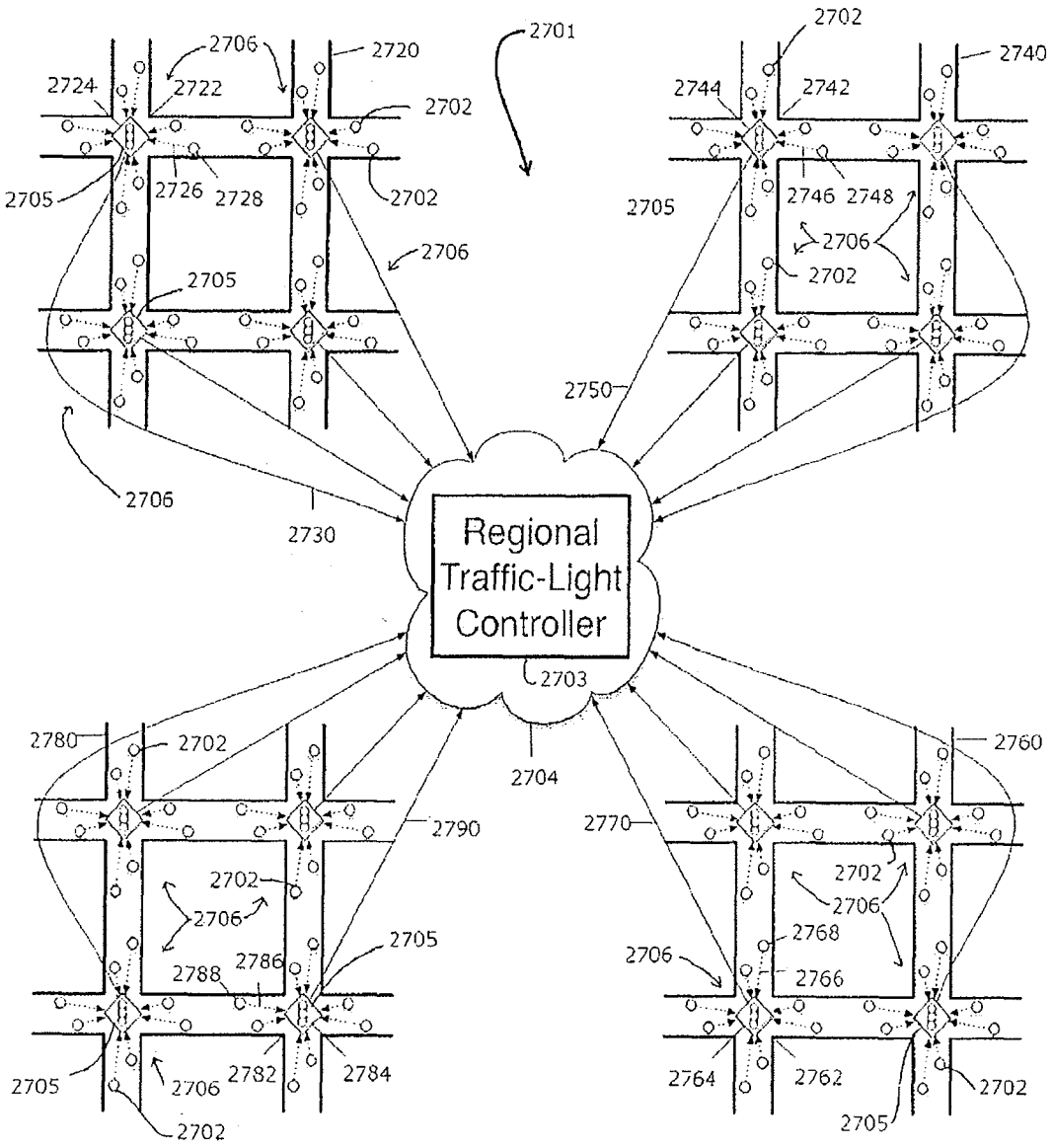

Regional
Traffic-Light
Controller
2701
2702
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Figure 27

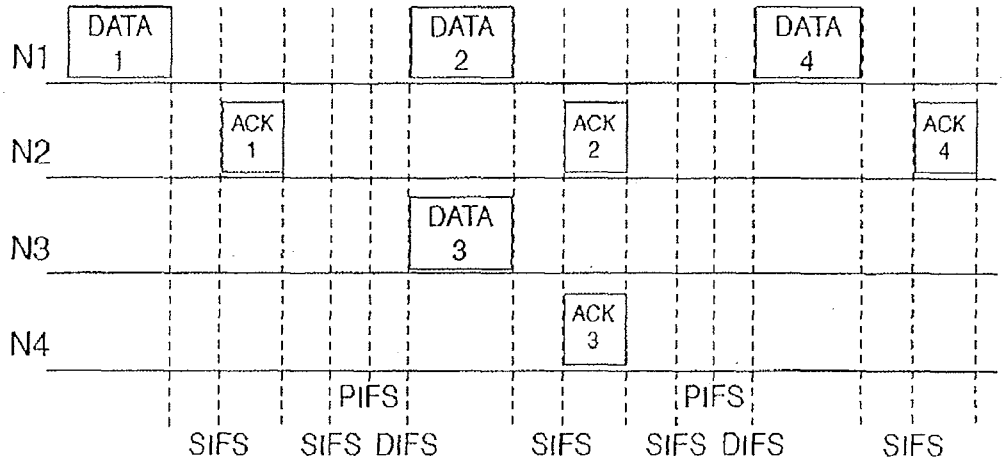
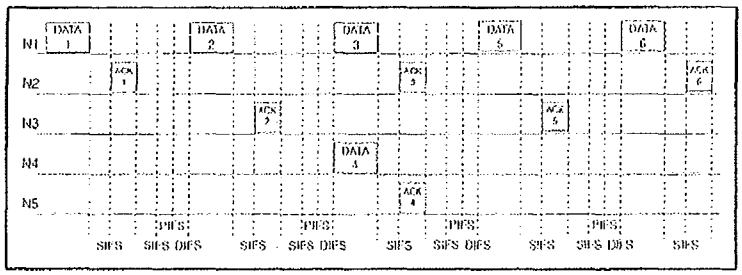
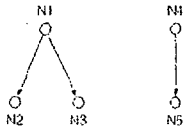

N1
N2
N3
N4
DATA 1
ACK 1
DATA 2
DATA 3
ACK 2
ACK 3
DATA 4
ACK 4
PIFS
PIFS
SIFS
SIFS
DIFS
SIFS
SIFS
DIFS
SIFS

Figure 28





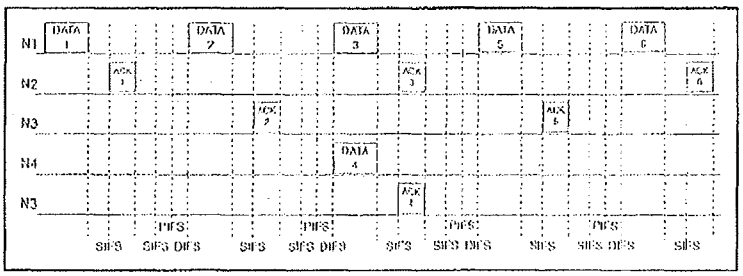
Notes:

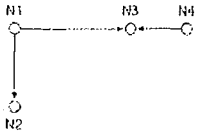
1. ACK frame contains a sequence number or a collision detection pattern.

2. Arrow points from transmitter of DATA frame to receiver of DATA frame.

3. In a distributed network, collision detection patterns used by N2 and N3 in their ACKs may not be coordinated. Longer collision detection patterns may reduce the probability that N2 and N3 use the same collision detection numbers at any given point in time. This may further robustly facilitate extra ACK snooping.

4. In the example scenario, N4 uses extra ACK snooping to test the feasibility of its transmission to N5 in parallel with N1's transmission to N2. Thus, extra ACK snooping may improve robustness and correctness of the collision detection mechanism in scenarios with multiple client nodes.





Notes:

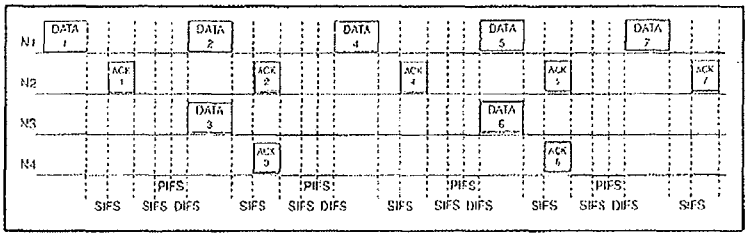
1. ACK frame contains a sequence number or a collision detection pattern.

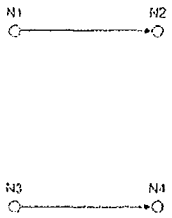
2. Arrow points from transmitter of DATA frame to receiver of DATA frame.

3. In a distributed network, collision detection patterns used by N2 and N3 in their ACKs may not be coordinated. Longer collision detection patterns may reduce the probability that N2 and N3 use the same collision detection numbers at any given point in time. This may further robustly facilitate extra ACK snooping.

4. In the example scenario, N4 uses extra ACK snooping to test the feasibility of its transmission to N3 in parallel with N1's transmission to N2. Thus, extra ACK snooping may improve robustness and correctness of the collision detection mechanism in scenarios with multiple client nodes.

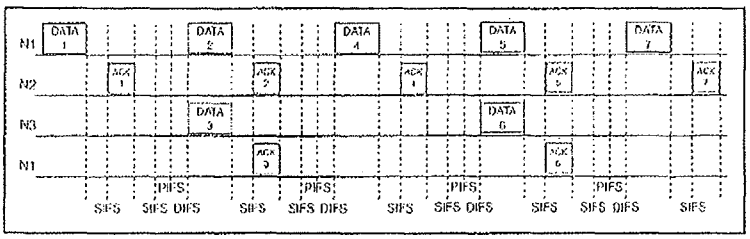
Figure 29

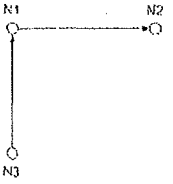




Notes:

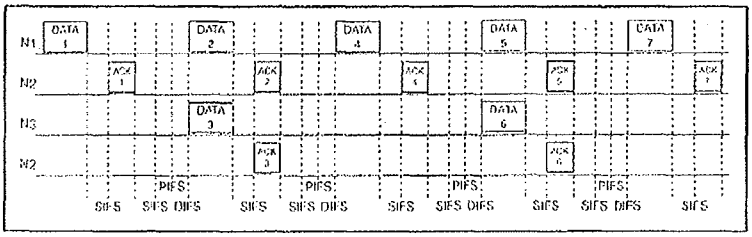
1. ACK frame contains a sequence number or a collision detection pattern.
2. Arrow points from transmitter of DATA frame to receiver of DATA frame.
3. More ACK snooping may improve robustness.

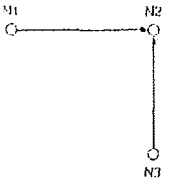




Notes:

1. ACK frame contains a sequence number or a collision detection pattern.
2. Arrow points from transmitter of DATA frame to receiver of DATA frame.
3. More ACK snooping may improve robustness.
4. N1 is capable of transmitting and receiving at the same time.

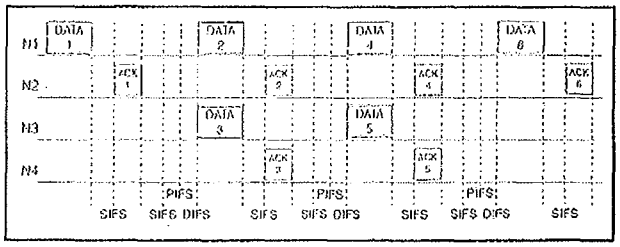


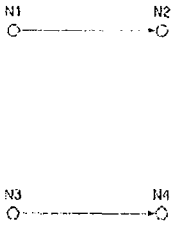


Notes:

1. ACK frame contains a sequence number or a collision detection pattern.
2. Arrow points from transmitter of DATA frame to receiver of DATA frame.
3. More ACK snooping may improve robustness.
4. N2 is capable of transmitting and receiving multiple frames at the same time.

Figure 30





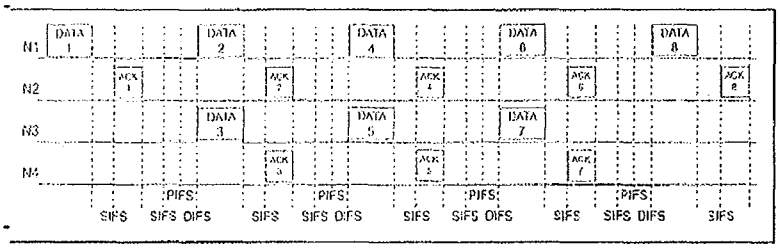
Notes:

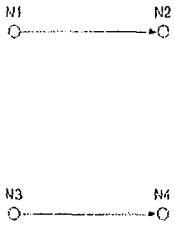
1. ACK frame contains a sequence number or a collision detection pattern.

2. Arrow points from transmitter of DATA frame to receiver of DATA frame.

3. More ACK snooping may improve robustness.

4. Consecutive ACK snooping may require longer sequence numbers or collision detection patterns.





Notes:

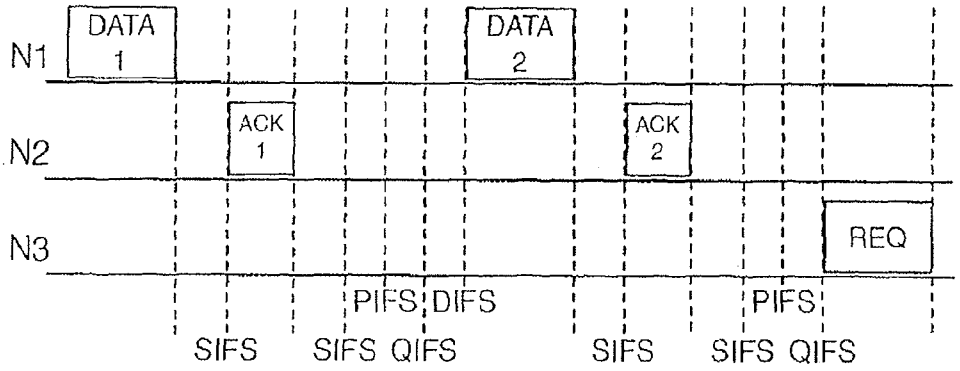
1. ACK frame contains a sequence number or a collision detection pattern.

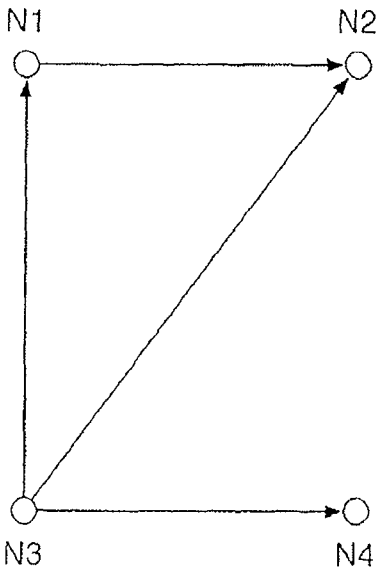
2. Arrow points from transmitter of DATA frame to receiver of DATA frame.

3. More ACK snooping may improve robustness.

4. Consecutive ACK snooping may require longer sequence numbers or collision detection patterns.

Figure 31





Notes:

1. Arrow points from transmitter of DATA frame to receiver of DATA frame.

2. REQ frames are used to exchange signaling between nodes. REQ frame could be a DATA frame.

3. REQ frames may be broadcast.

4. N4 is not shown in above diagram to prevent clutter.

Figure 32