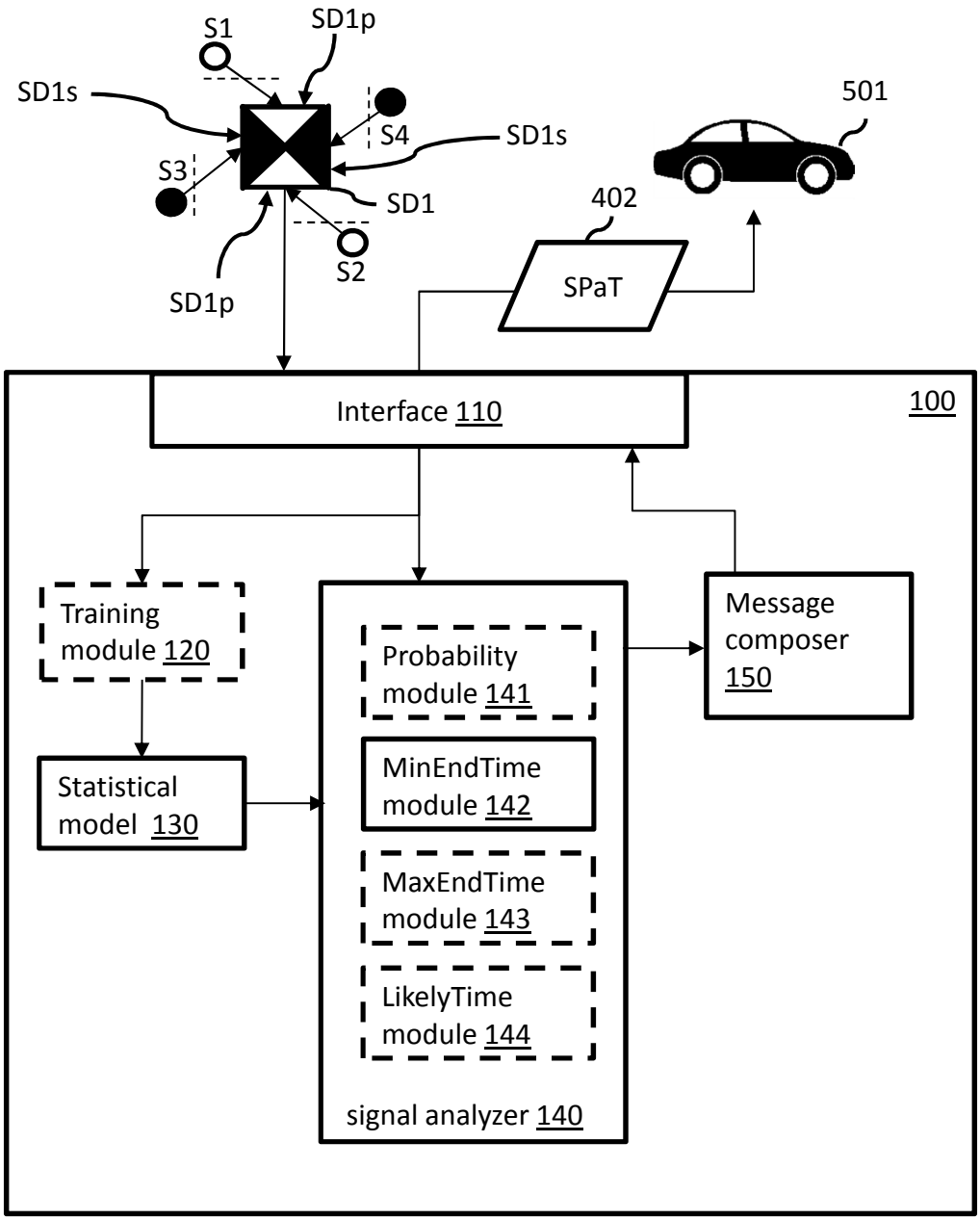

S1
SD1p
SD1s
S4
SD1s
S3
SD1
S2
SD1p
501
402
SPaT
100
Interface 110
Training module 120
Statistical model 130
Probability module 141
MinEndTime module 142
MaxEndTime module 143
LikelyTime module 144
signal analyzer 140
Message composer 150

FIG. 1

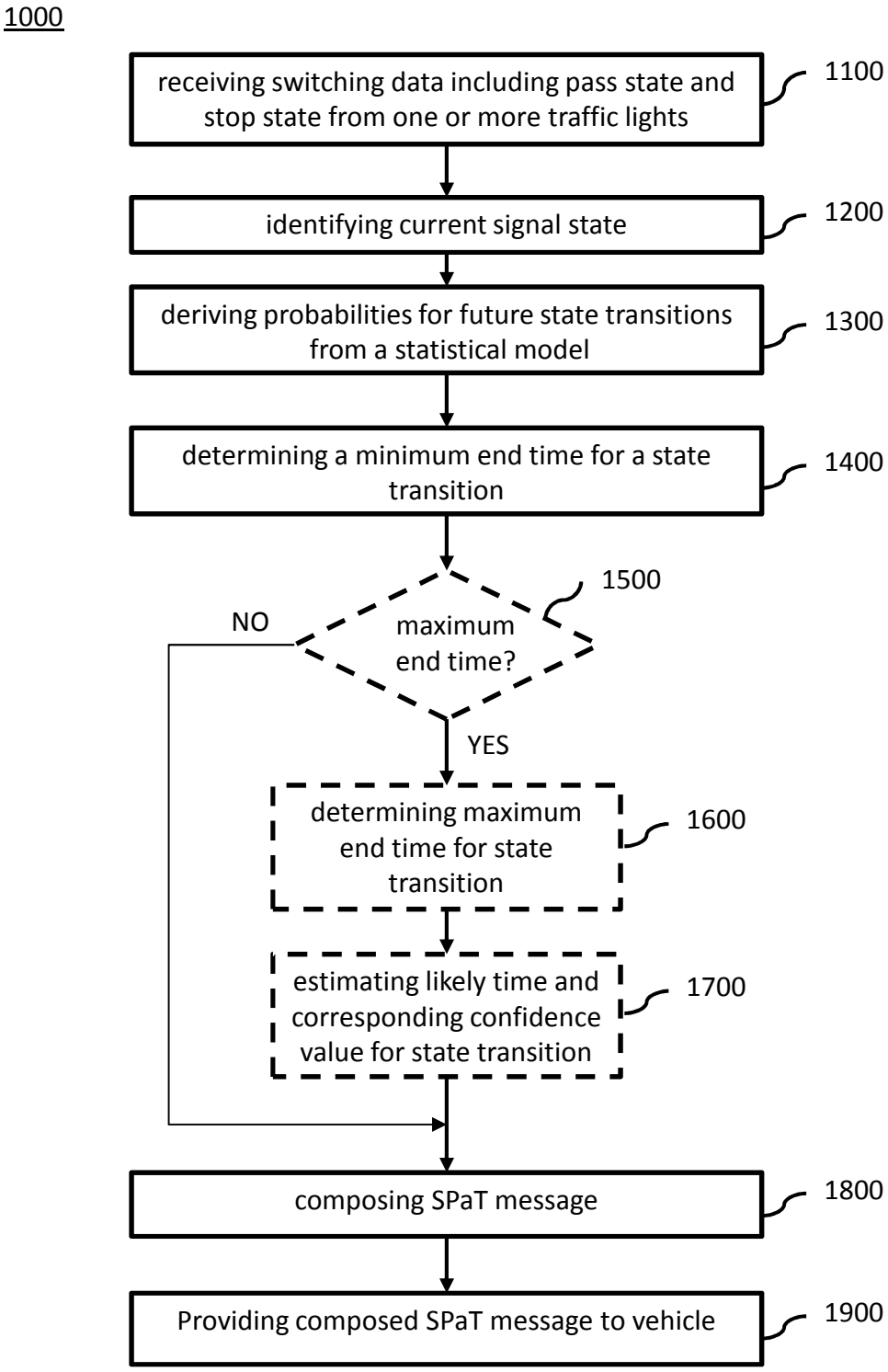

1000
receiving switching data including pass state and stop state from one or more traffic lights
1100
identifying current signal state
1200
deriving probabilities for future state transitions from a statistical model
1300
determining a minimum end time for a state transition
1400
maximum end time?
1500
NO
YES
determining maximum end time for state transition
1600
estimating likely time and corresponding confidence value for state transition
1700
composing SPaT message
1800
Providing composed SPaT message to vehicle
1900

FIG. 2

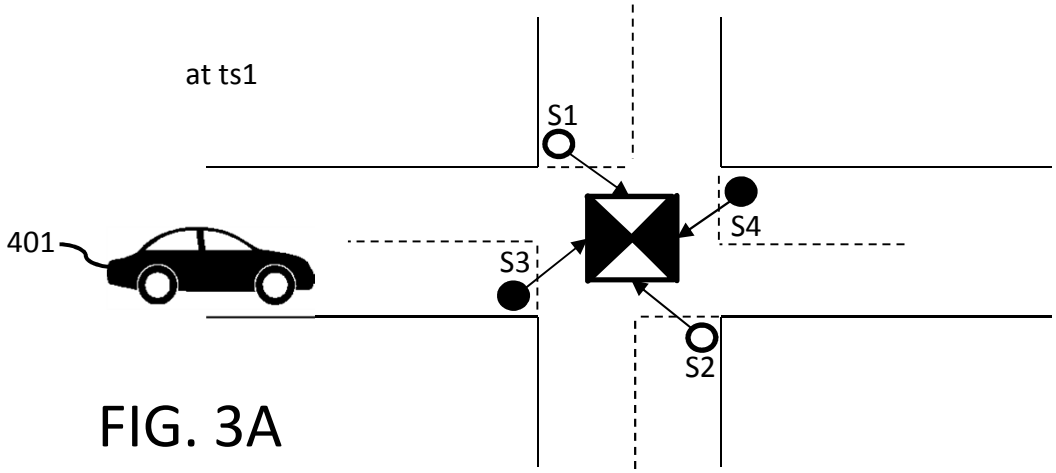


FIG. 3A

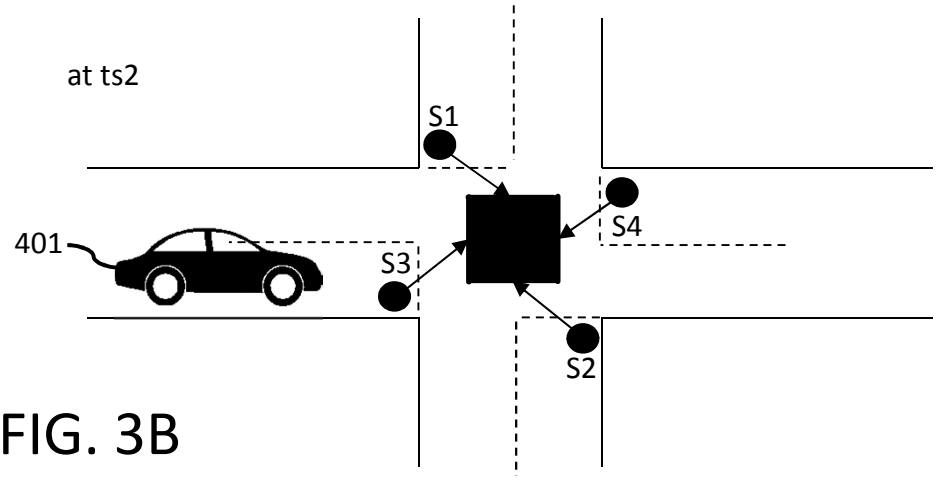


FIG. 3B

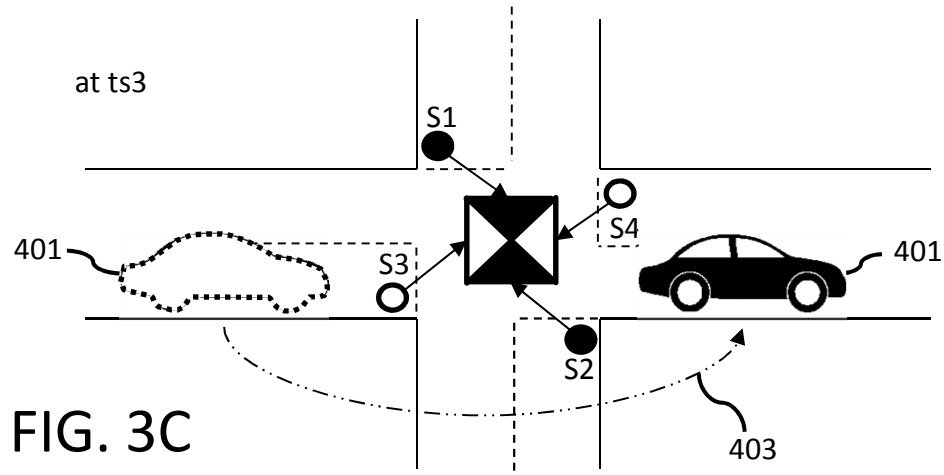


FIG. 3C

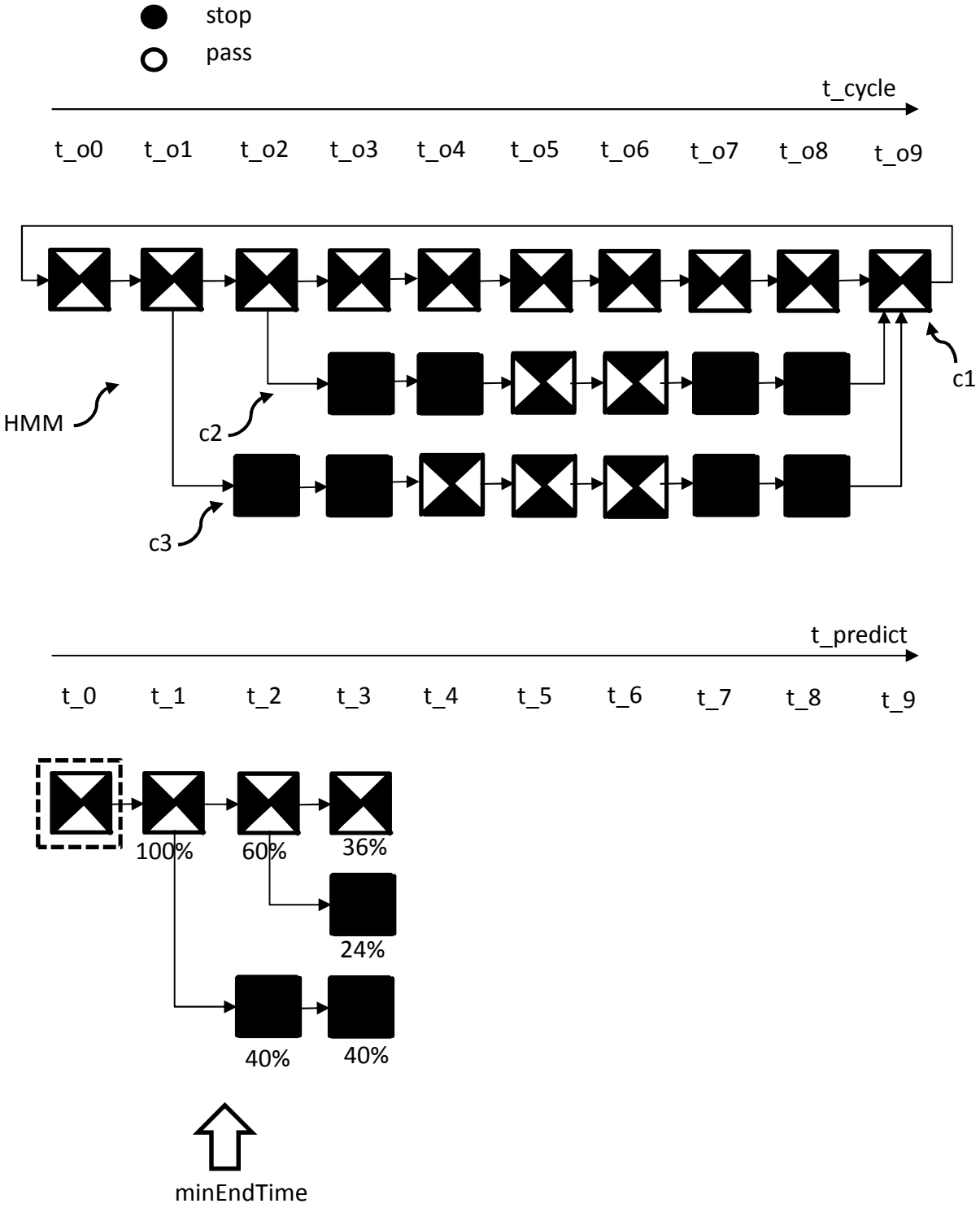

stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
HMM
c1
c2
c3
t_predict
t_0
t_1
t_2
t_3
t_4
t_5
t_6
t_7
t_8
t_9
100%
60%
36%
24%
40%
40%
minEndTime

FIG. 4A

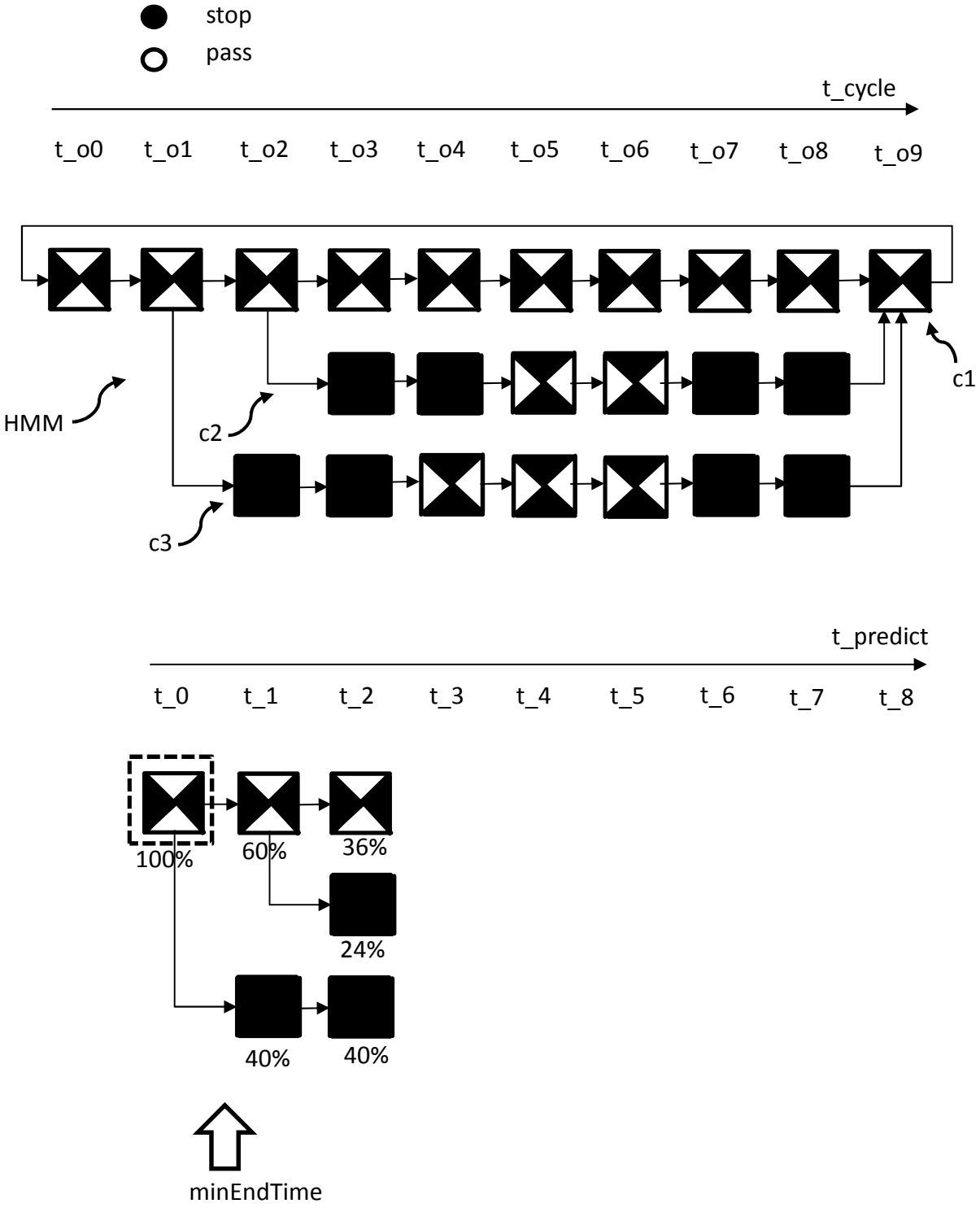

stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
HMM
c1
c2
c3
t_predict
t_0
t_1
t_2
t_3
t_4
t_5
t_6
t_7
t_8
100%
60%
36%
24%
40%
40%
minEndTime

FIG. 4B

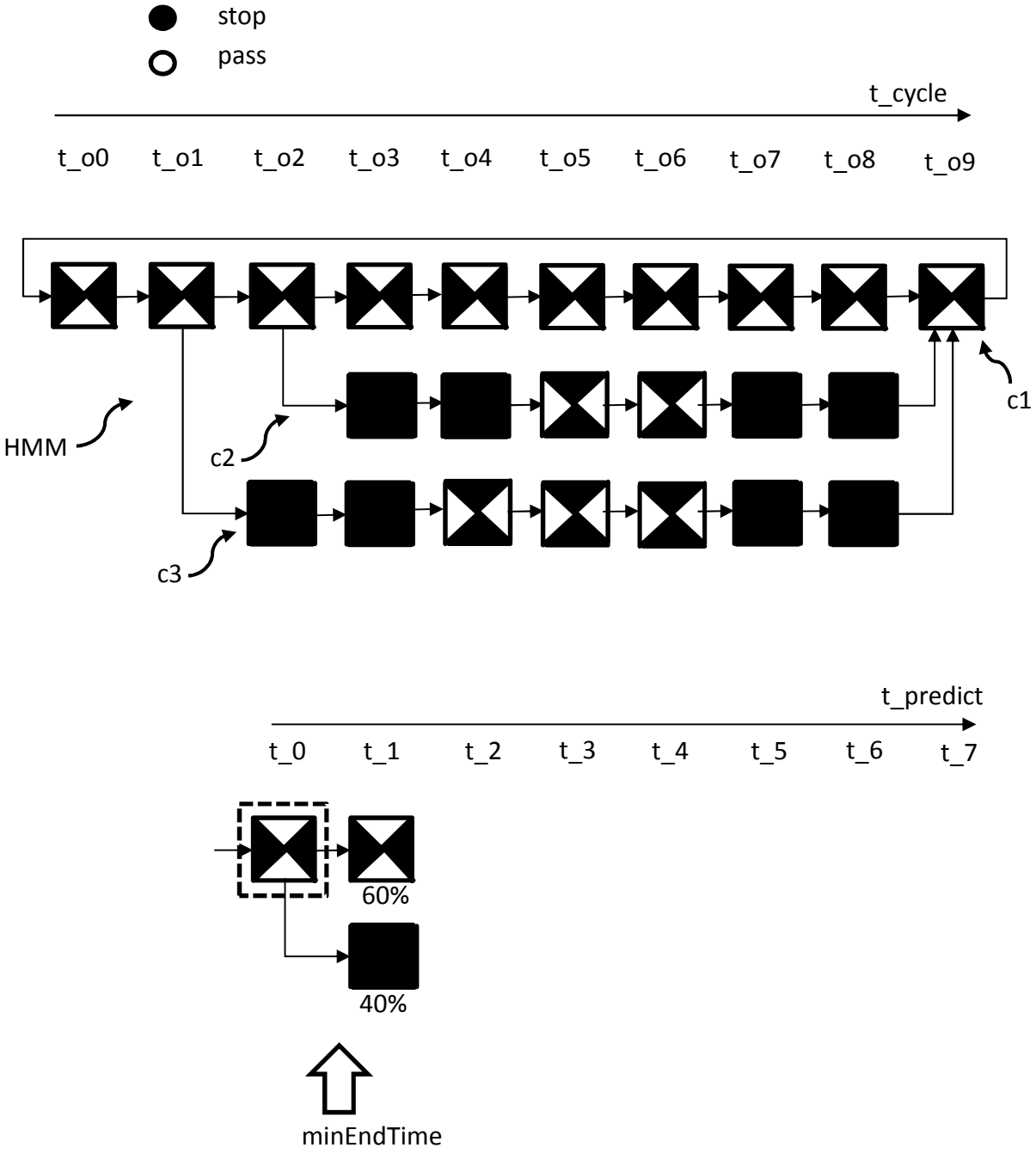

stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
HMM
c1
c2
c3
t_predict
t_0
t_1
t_2
t_3
t_4
t_5
t_6
t_7
60%
40%
minEndTime

FIG. 4C

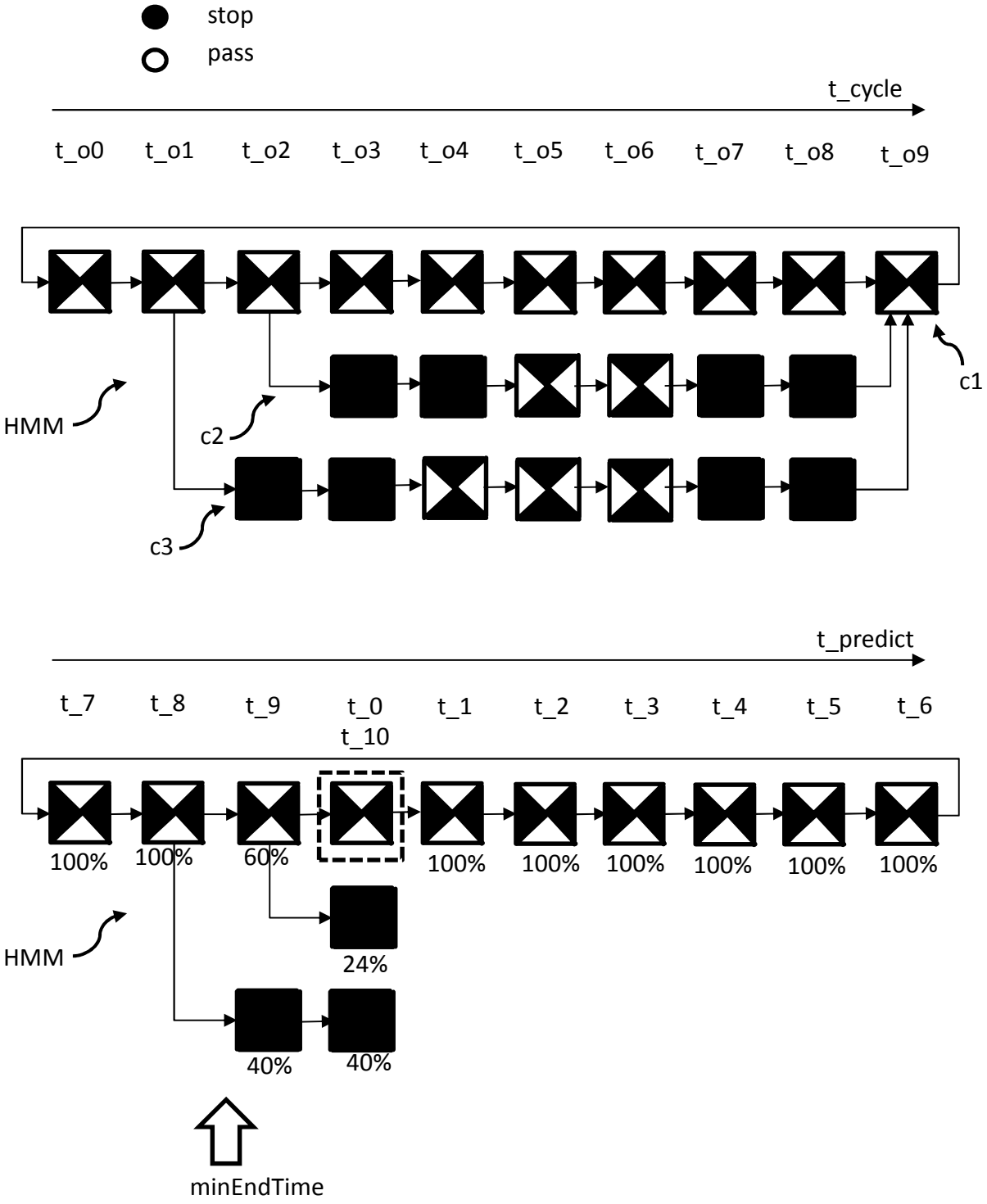

stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
HMM
c2
c3
c1
t_predict
t_7
t_8
t_9
t_0
t_10
t_1
t_2
t_3
t_4
t_5
t_6
100%
100%
60%
100%
100%
100%
100%
100%
100%
HMM
24%
40%
40%
minEndTime

FIG. 4D

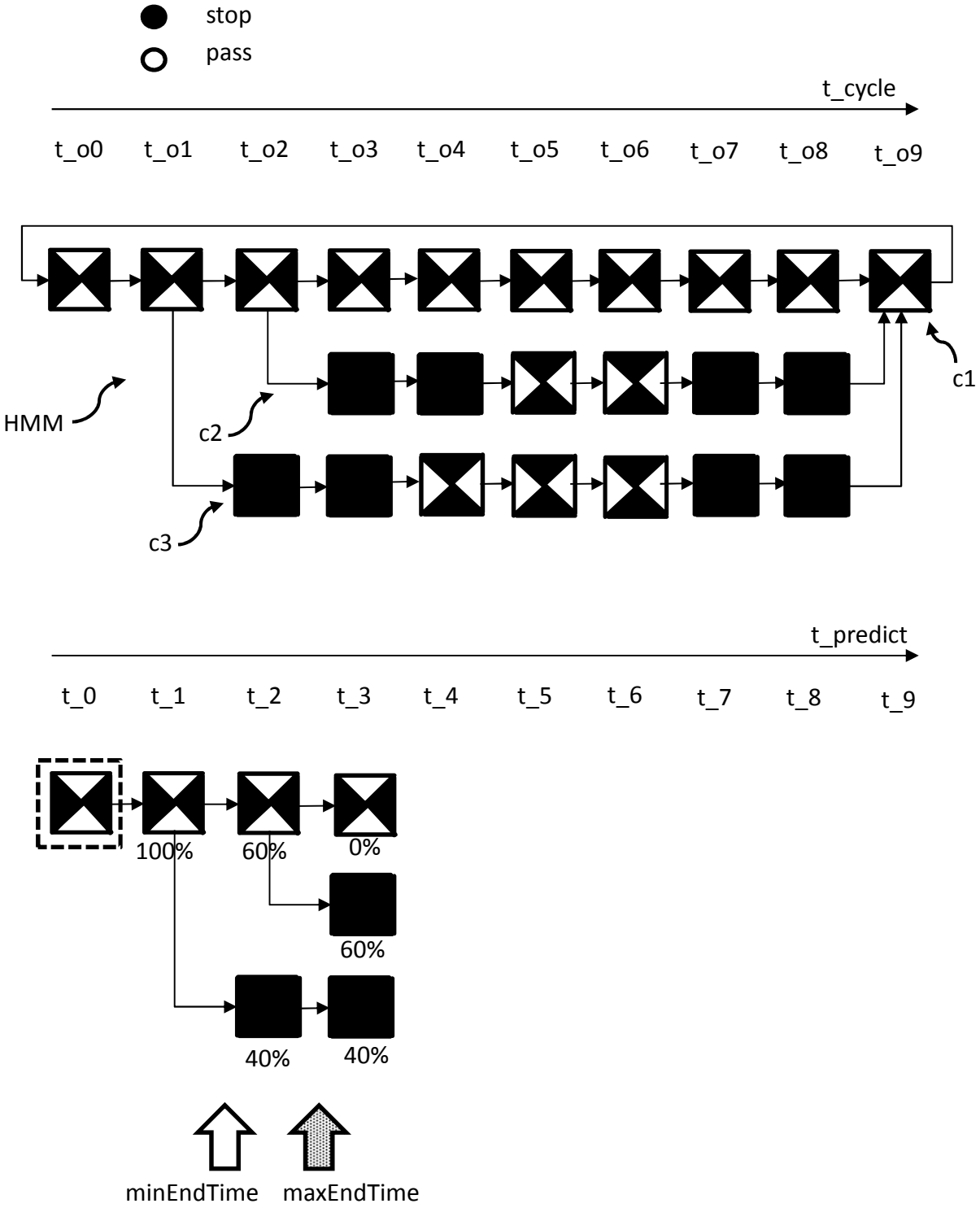
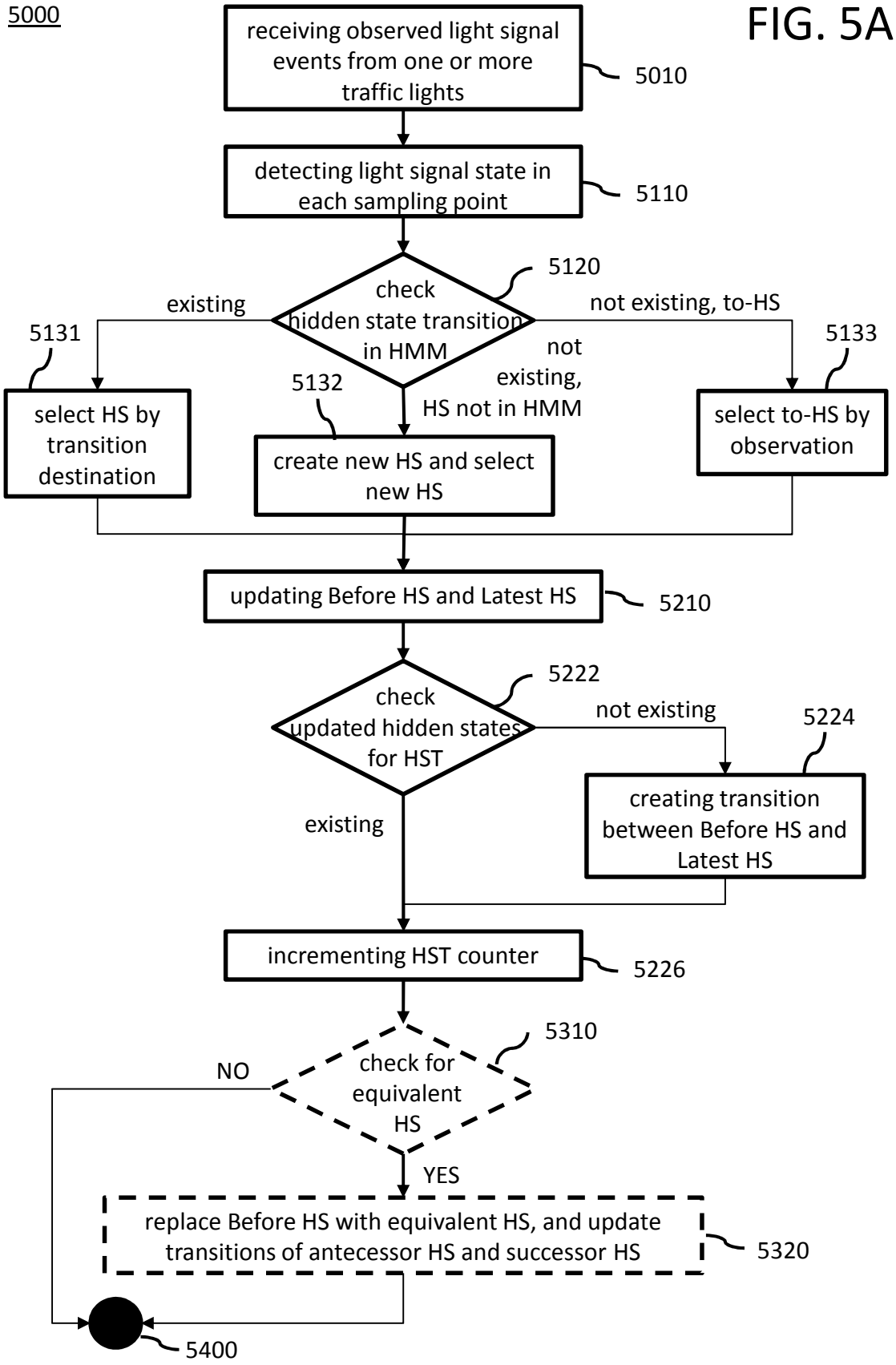

stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
HMM
c1
c2
c3
t_predict
t_0
t_1
t_2
t_3
t_4
t_5
t_6
t_7
t_8
t_9
100%
60%
0%
60%
40%
40%
minEndTime
maxEndTime

FIG. 4E

FIG. 5A


5000
receiving observed light signal events from one or more traffic lights
5010
detecting light signal state in each sampling point
5110
check hidden state transition in HMM
5120
existing
not existing, to-HS
not existing, HS not in HMM
5131
5132
5133
select HS by transition destination
create new HS and select new HS
select to-HS by observation
updating Before HS and Latest HS
5210
check updated hidden states for HST
5222
not existing
5224
existing
creating transition between Before HS and Latest HS
incrementing HST counter
5226
check for equivalent HS
5310
NO
YES
replace Before HS with equivalent HS, and update transitions of antecessor HS and successor HS
5320
5400

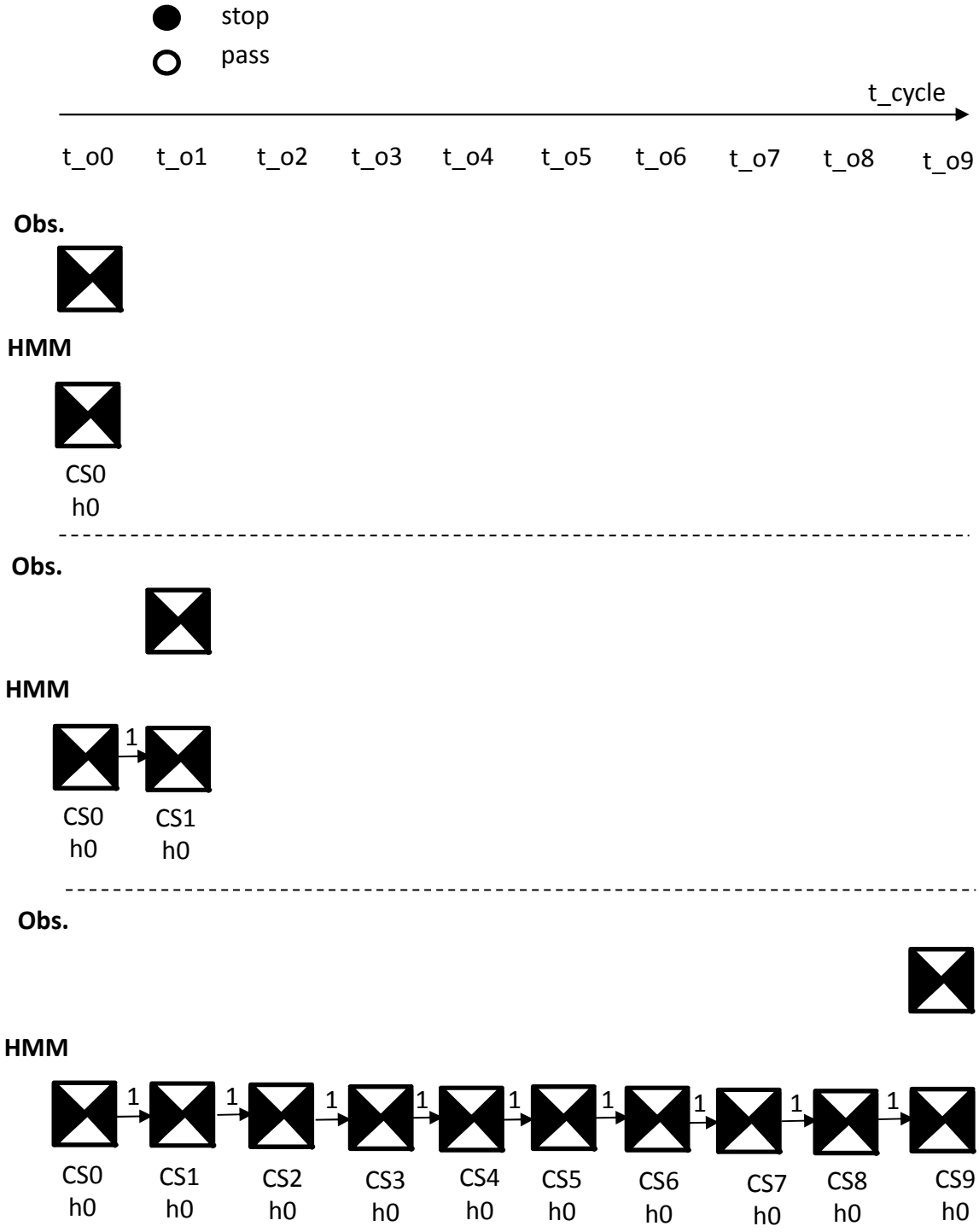
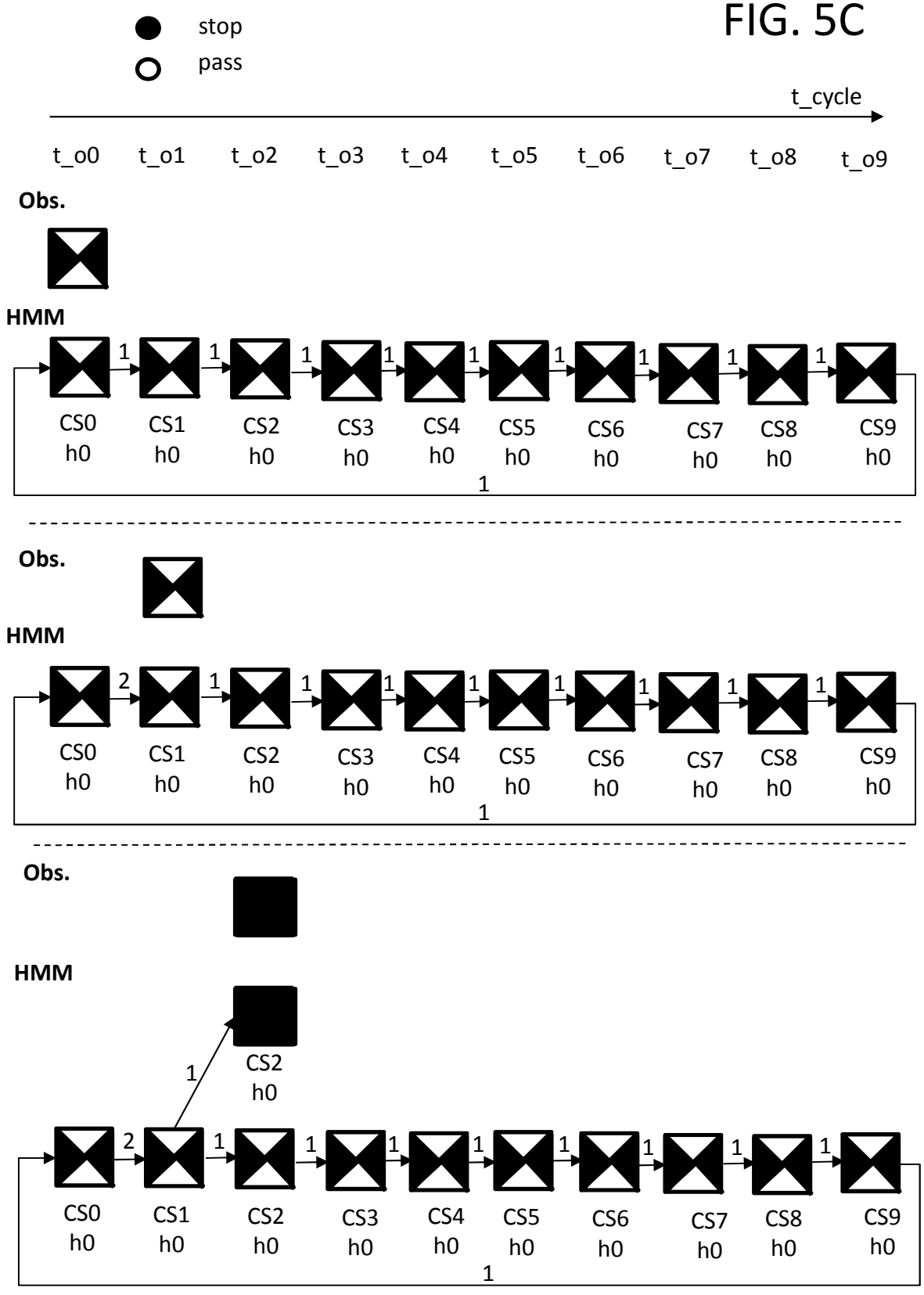

stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
Obs.
HMM
CS0
h0
Obs.
HMM
1
CS0
h0
CS1
h0
Obs.
HMM
1
1
1
1
1
1
1
1
1
CS0
h0
CS1
h0
CS2
h0
CS3
h0
CS4
h0
CS5
h0
CS6
h0
CS7
h0
CS8
h0
CS9
h0

FIG. 5B

FIG. 5C


stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
Obs.
HMM
CS0 h0
CS1 h0
CS2 h0
CS3 h0
CS4 h0
CS5 h0
CS6 h0
CS7 h0
CS8 h0
CS9 h0
Obs.
HMM
Obs.
HMM
CS2 h0

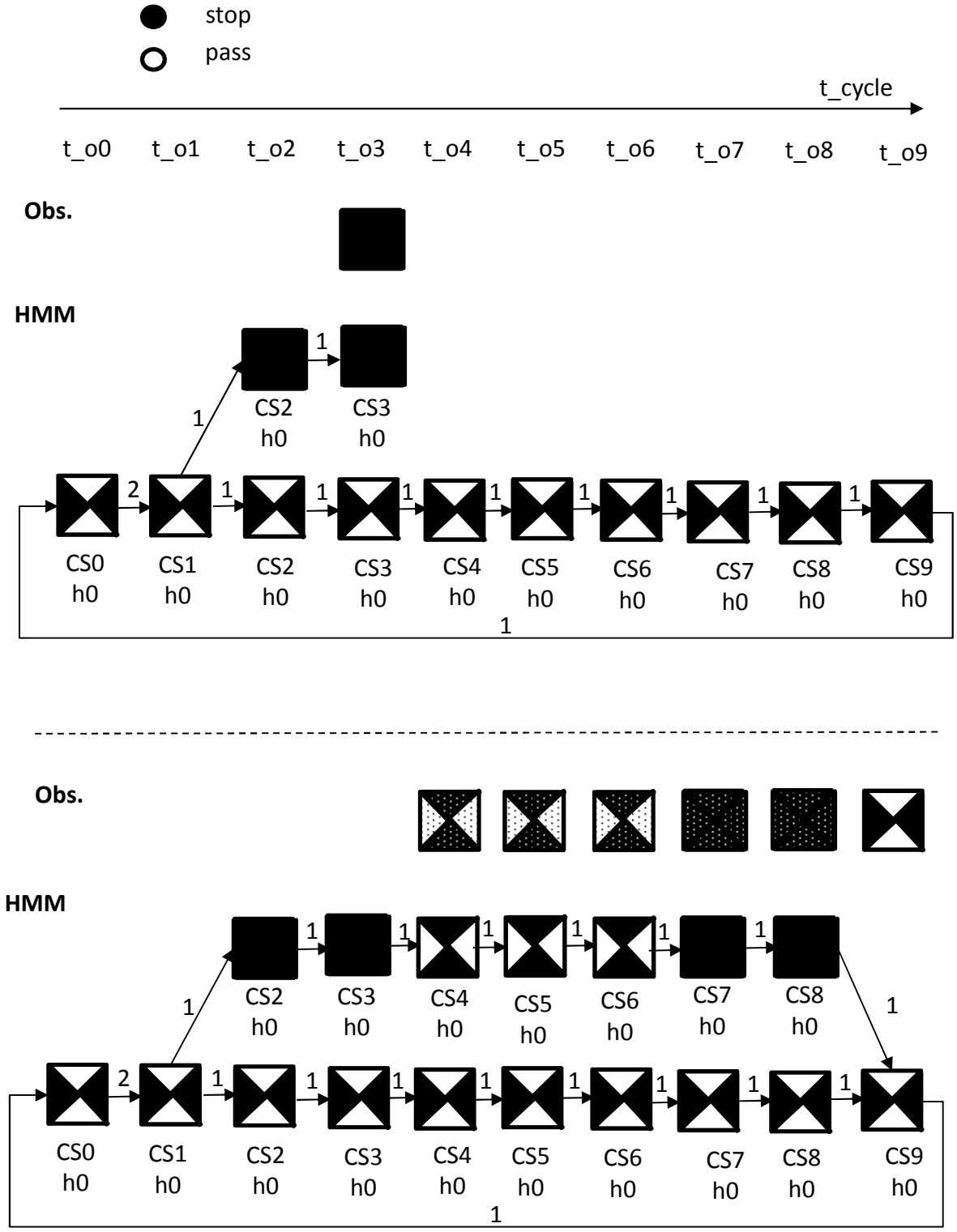

stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
Obs.
HMM
CS0 h0
CS1 h0
CS2 h0
CS3 h0
CS4 h0
CS5 h0
CS6 h0
CS7 h0
CS8 h0
CS9 h0
Obs.
HMM

FIG. 5D

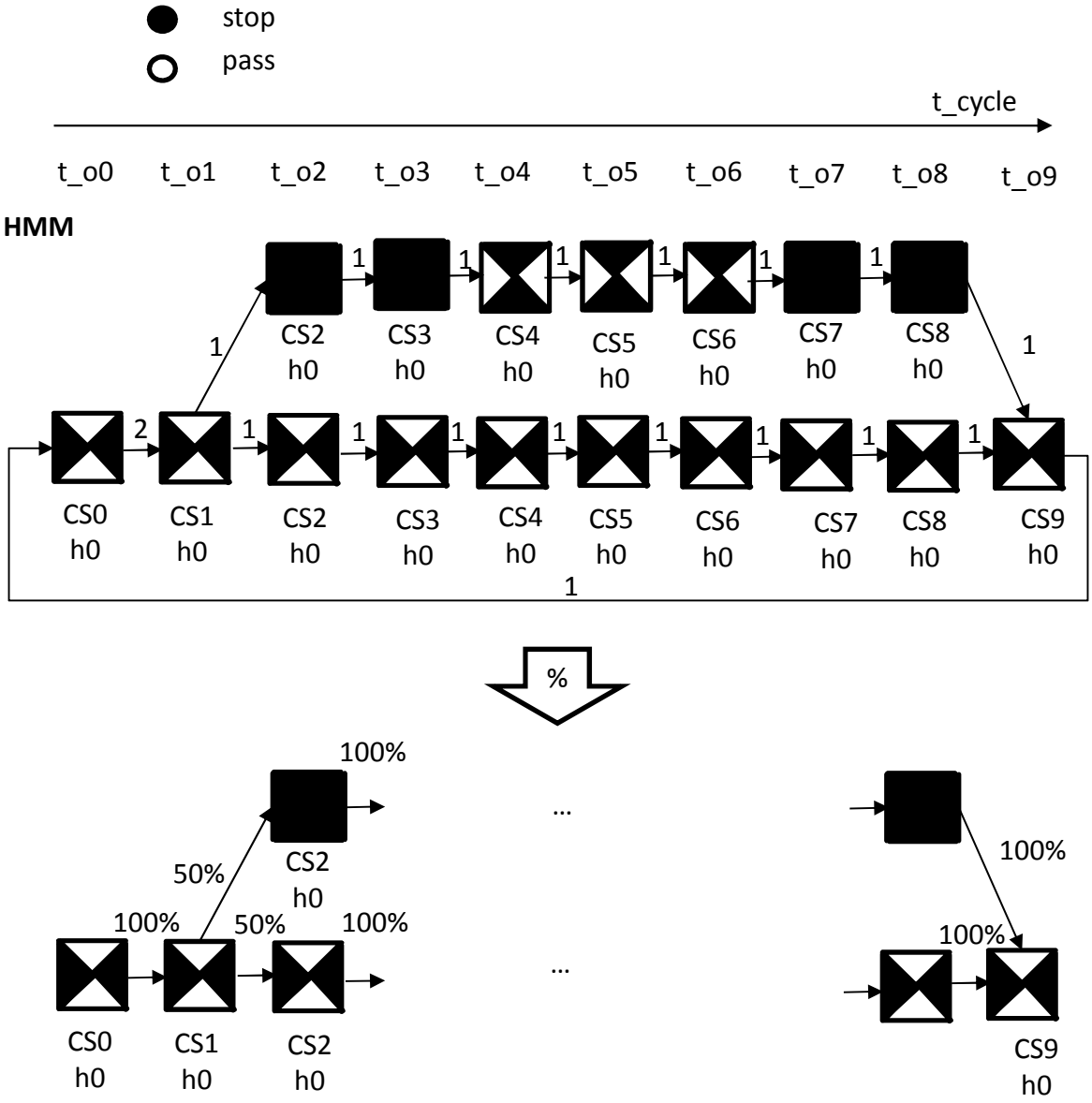

stop
pass
t_cycle
t_o0
t_o1
t_o2
t_o3
t_o4
t_o5
t_o6
t_o7
t_o8
t_o9
HMM
CS0 h0
CS1 h0
CS2 h0
CS3 h0
CS4 h0
CS5 h0
CS6 h0
CS7 h0
CS8 h0
CS9 h0
%
100%
50%
...

FIG. 5E

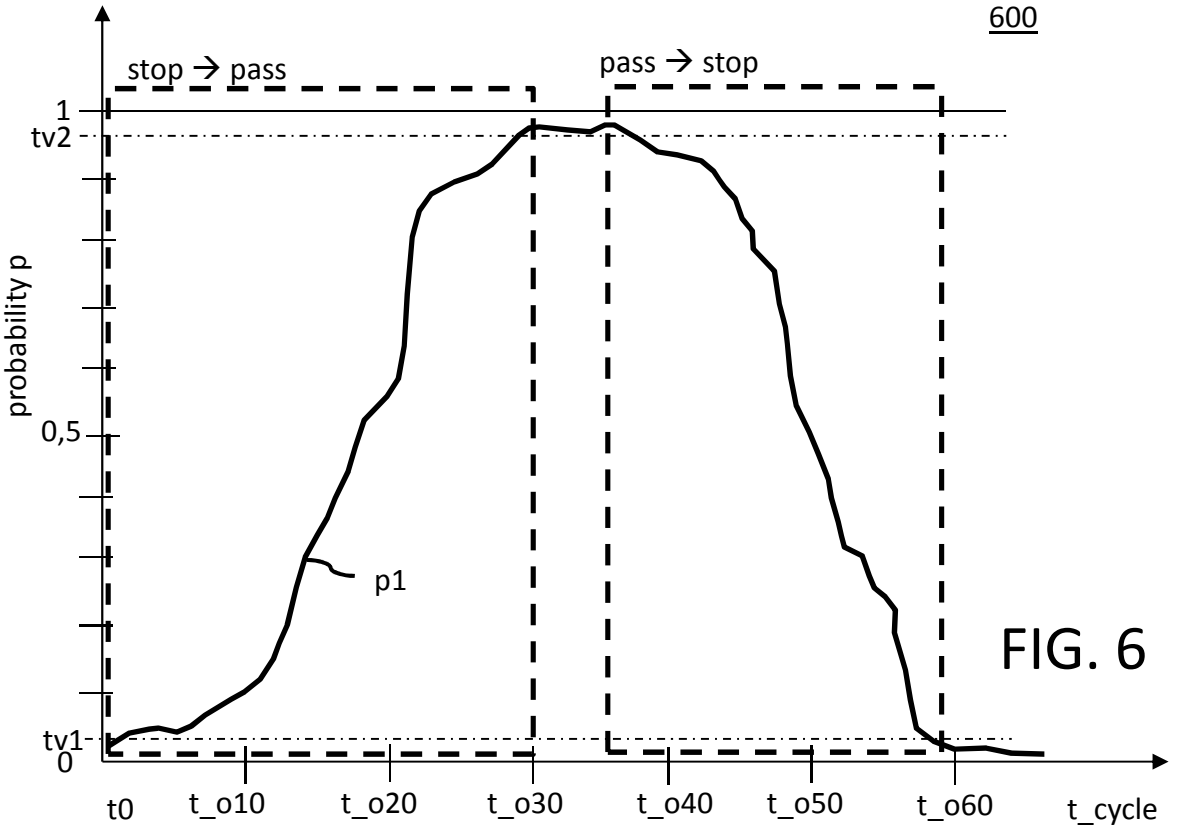

600
stop → pass
pass → stop
1
tv2
probability p
0,5
p1
tv1
0
t0
t_o10
t_o20
t_o30
t_o40
t_o50
t_o60
t_cycle

FIG. 6

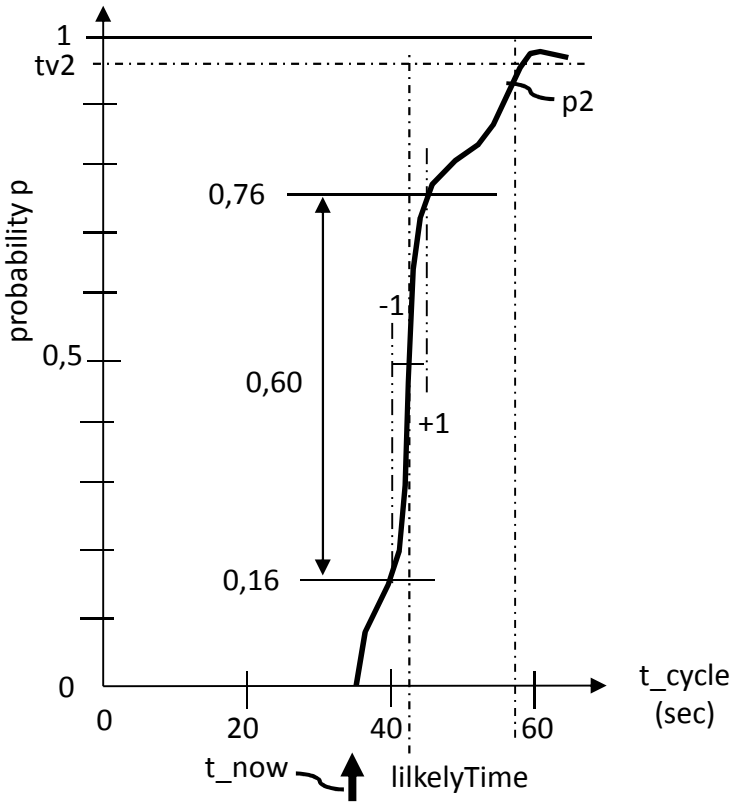

1
tv2
p2
probability p
0,76
-1
0,5
0,60
+1
0,16
0
0
20
40
60
t_cycle
(sec)
t_now
likelyTime

FIG. 8C

700

	Cycle sec. t	0	1	2	3	4	5	6	7	8	9
711	Record 1 at absolute time 0:00*	0:00	0:01	0:02	0:03	0:04	0:05	0:06	0:07	0:08	0:09
	Record 2 at absolute time 0:10*	0:10	0:11	0:12	0:13	0:14	0:15	0:16	0:17	0:18	0:19
	Record 3 at absolute time 0:20*	0:20	0:21	0:22	0:23	0:24	0:25	0:26	0:27	0:28	0:29
710	r_t	3	3	3	3	2	1	0	0	2	3
	g_t	0	0	0	0	1	2	3	3	1	0
	p_t	0	0	0	0	0.33	0.67	1	1	0.33	0

FIG. 7A

720

Absolute time	0:30	0:31	0:32	0:33	0:34	0:35	0:36	0:37	0:38	0:39
Cycle sec. t	0	1	2	3	4	5	6	7	8	9
p_t	0	0	0	0	0.33	0.67	1	1	0.33	0
MinET rg				x						
MaxET rg							x			
MinET gr								x		
MaxET gr										x

FIG. 7B

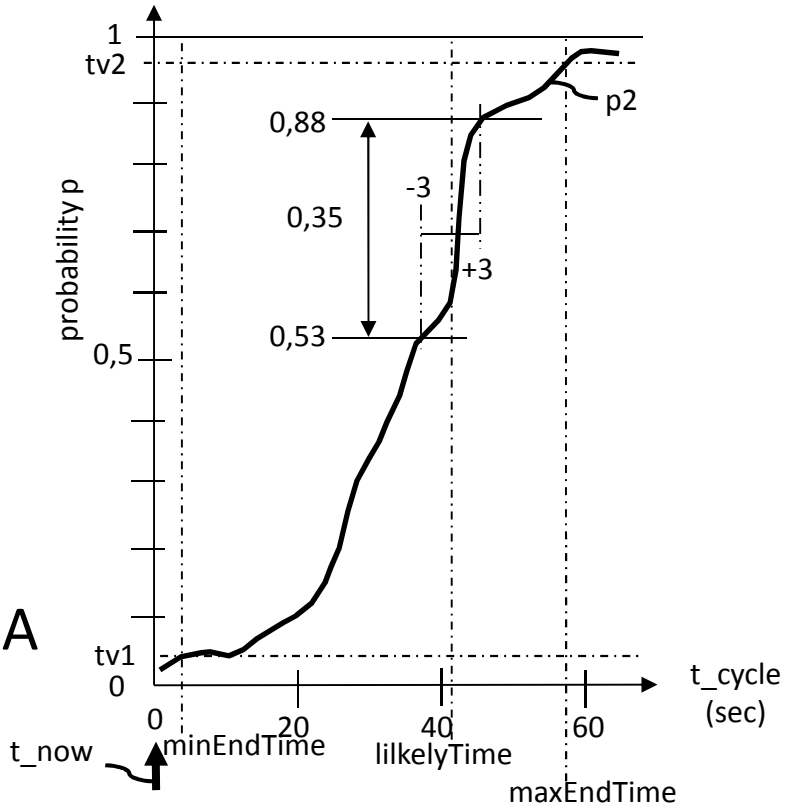

1
tv2
p2
0,88
0,35
-3
+3
0,53
probability p
0,5
tv1
0
0
20
40
60
t_cycle
(sec)
t_now
minEndTime
lilkelyTime
maxEndTime

FIG. 8A

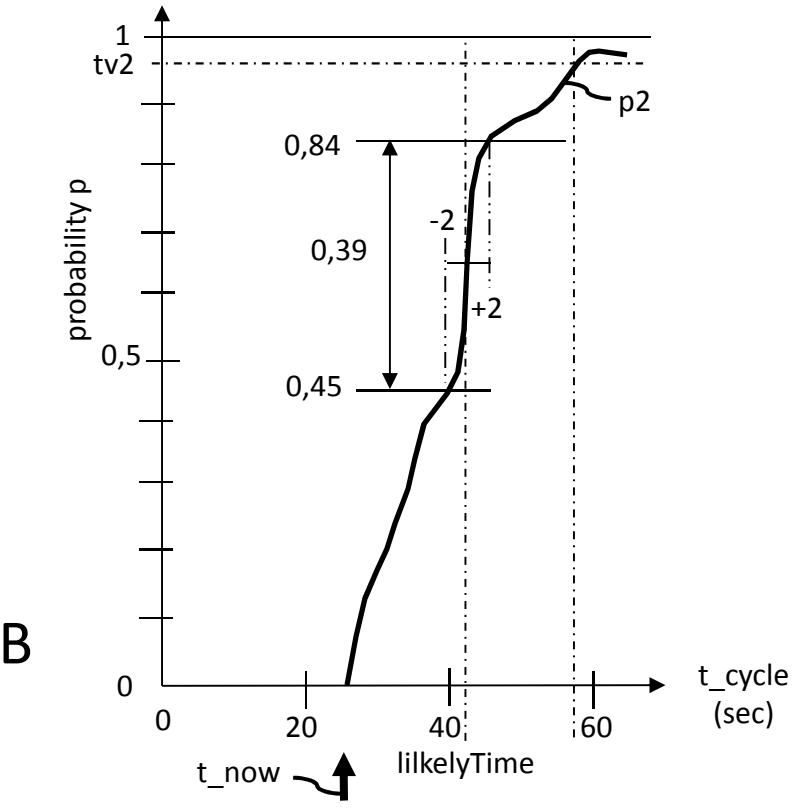

1
tv2
p2
0,84
0,39
-2
+2
0,45
probability p
0,5
0
0
20
40
60
t_cycle
(sec)
t_now
lilkelyTime

FIG. 8B

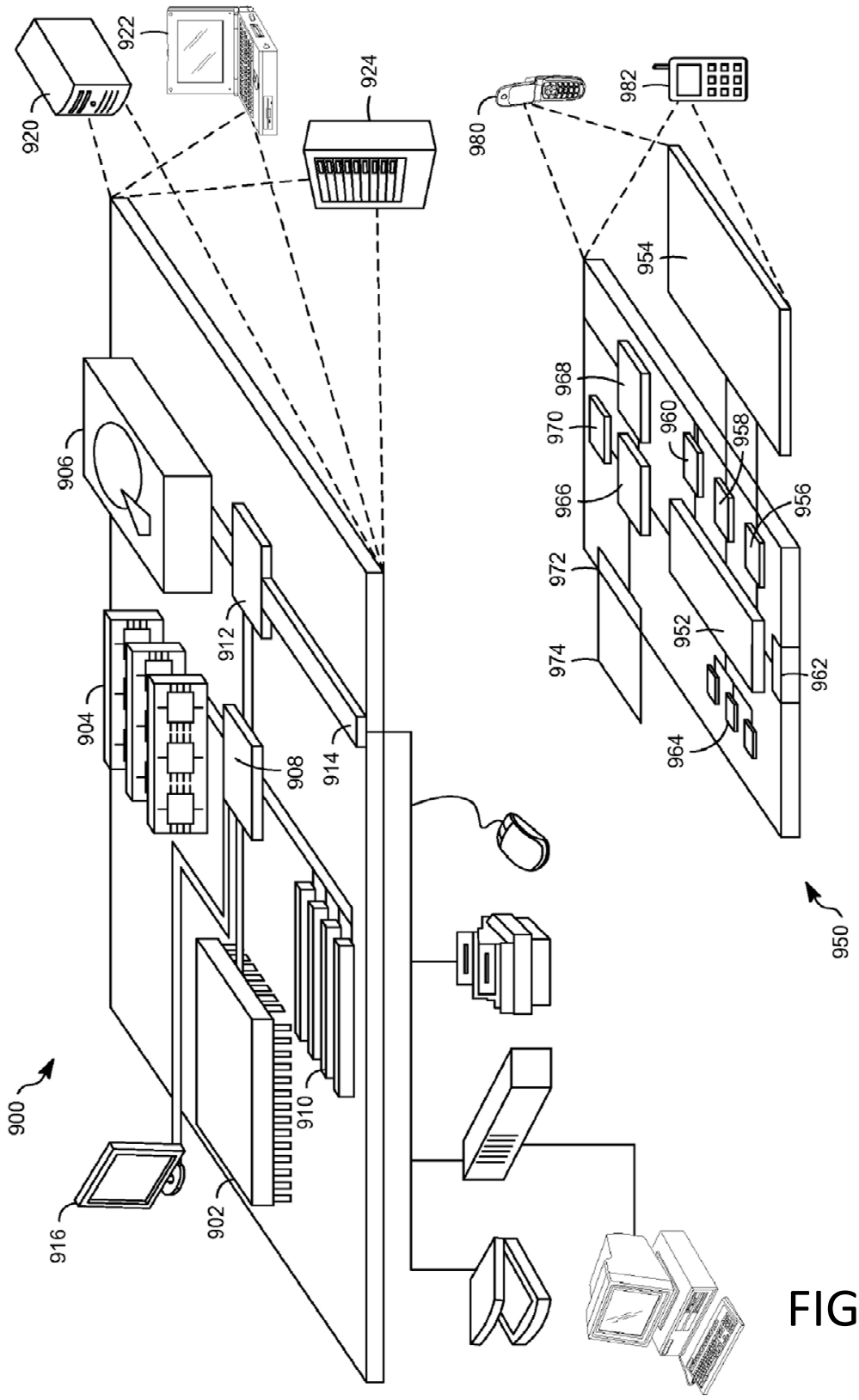

900
902
904
906
908
910
912
914
916
920
922
924
950
952
954
956
958
960
962
964
966
968
970
972
974
980
982

FIG. 9