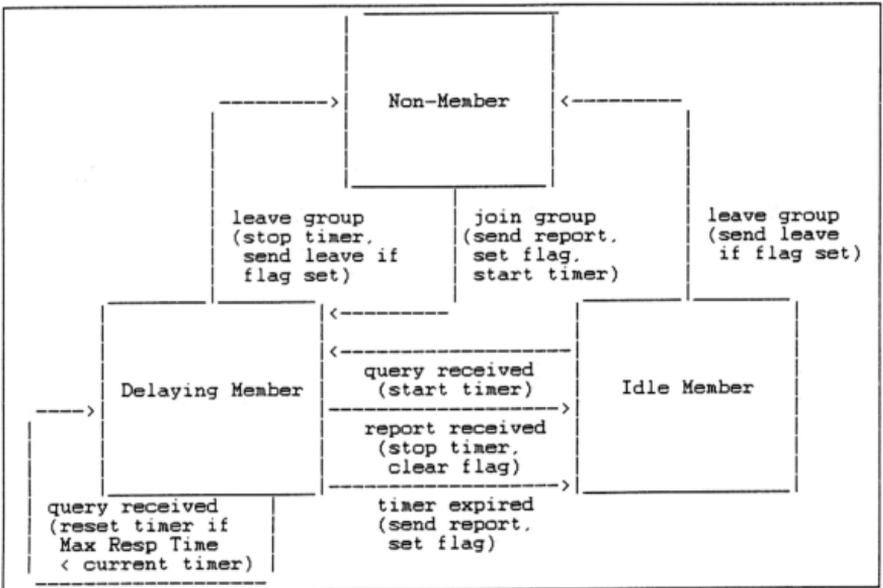


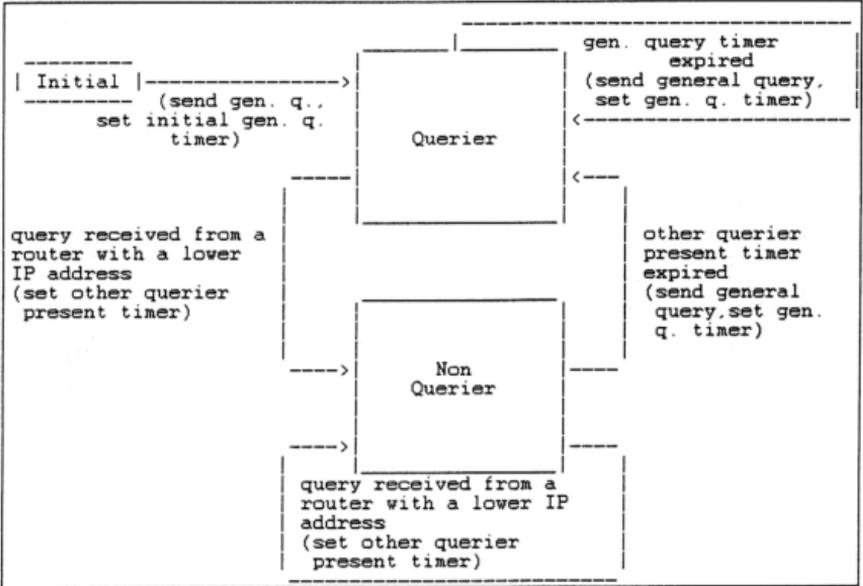
Appendix A

IGMP State Diagram

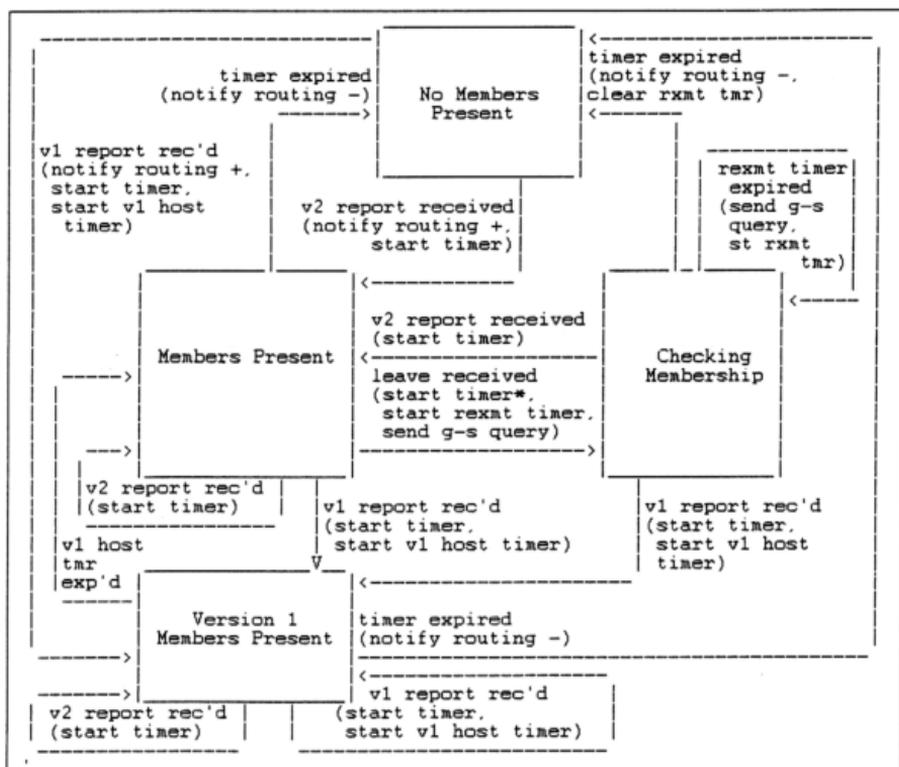
(1) State Diagram for Host



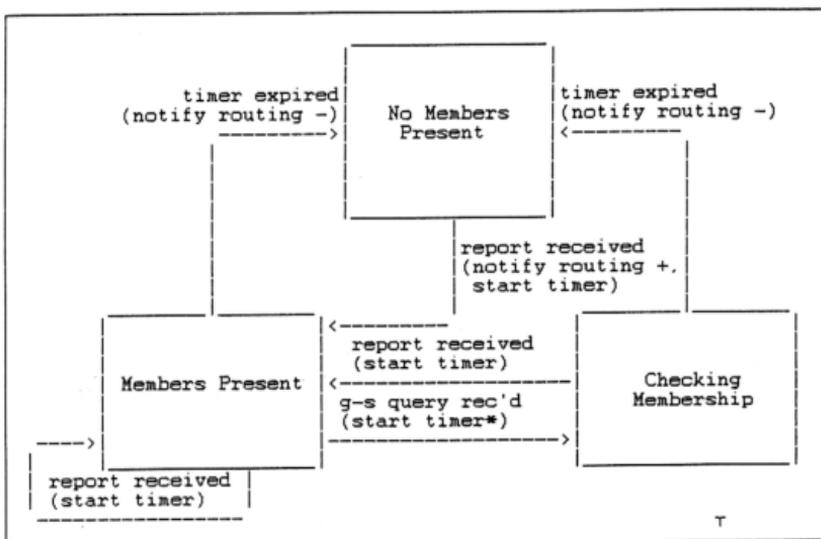
(2) State Diagram for Router



(3) State Diagram for Router (Querier)



(4) State Diagram for Router (non-Querier)



Appendix B

Constants used in *IGMPv2* class and *PIMDM* class

(1) Constant for *IGMPv2*

```
////////////////////////////////////
////IGMP TYPE ////
////////////////////////////////////
public static final int IGNORE =0x00;
public static final int QUERY = 0x11;
public static final int REPORT = 0x16;
public static final int LEAVE = 0x17;
public static final int VER1REPORT=0x12;

////////////////////////////////////
////HOST AND ROUTER STATE////
////////////////////////////////////

private static final int QUERIER=0;
private static final int NONQUERIER=1;
private static final int HOST=2;

////////////////////////////////////
////DEFAULT TIMER AND COUNT VALUE////
////////////////////////////////////
//scale factor = 0.2 original value is stated after the "/"
static int ROBUSTNESS_VARIABLE=2; //variable
static double QUERY_INTERVAL=25;//125;
static double QUERY_RESPONSE_INTERVAL=20;//100;
//variable in second
static double GROUP_MEMBERSHIP_INTERVAL =
        ((ROBUSTNESS_VARIABLE)*(QUERY_INTERVAL))+
        (QUERY_RESPONSE_INTERVAL);
static double OTHER_QUERIER_PRESENT_INTERVAL=
        ((ROBUSTNESS_VARIABLE)*(QUERY_INTERVAL))+((3/2)*
        (QUERY_RESPONSE_INTERVAL));
static double STARTUP_QUERY_INTERVAL=(1/4)*(QUERY_INTERVAL);
static int STARTUP_QUERY_COUNT=(ROBUSTNESS_VARIABLE);
static double LAST_MEMBER_QUERY_INTERVAL=2; //10second
static int LAST_MEMBER_QUERY_COUNT=(ROBUSTNESS_VARIABLE);
static double UNSOLICITED_REPORT_INTERVAL=2;//10 second;
static double VERSION1_ROUTER_PRESENT_TIMEOUT=80;//400 second;

////////////////////////////////////
////IGMP EVENT TYPE////
////////////////////////////////////

public static final int EV_IGMP_RECEIVE=SimProvider.EV_PRIVATE + 101;
public static final int EV_IGMPOUTPUT=SimProvider.EV_PRIVATE + 110;
public static final int EV_IGMP_NOTIFICATIONADD=SimProvider.EV_PRIVATE
        + 111;
public static final int EV_IGMP_NOTIFICATIONREMOVE=
```

```
SimProvider.EV_PRIVATE + 112;
```

```
////////////////////////////////////  
////TIMER EVENT////  
////////////////////////////////////
```

```
public static final int EV_QUERY_INTERVAL =SimProvider.EV_PRIVATE +  
102;  
public static final int EV_QUERY_REPSONSE_INTERVAL =  
SimProvider.EV_PRIVATE + 103;  
public static final int EV_GROUP_MEMBERSHIP_INTERVAL =  
SimProvider.EV_PRIVATE + 104;  
public static final int EV_OTHER_QUERIER_PRESENT_INTERVAL =  
SimProvider.EV_PRIVATE + 105 ;  
public static final int EV_STARTUP_QUERY_INTERVAL =  
SimProvider.EV_PRIVATE + 106;  
public static final int EV_LAST_MEMBER_QUERY_INTERVAL  
=SimProvider.EV_PRIVATE + 107;  
public static final int EV_UNSOLICITED_REPORT_INTERVAL  
=SimProvider.EV_PRIVATE + 108;  
public static final int EV_VERSION1_ROUTER_PRESENT_INTERVAL  
=SimProvider.EV_PRIVATE + 109;
```

```
////////////////////////////////////  
////JOIN & LEAVE////  
////////////////////////////////////
```

```
public static final int JOINGROUP=0;  
public static final int LEAVEGROUP=1;
```

```
////////////////////////////////////  
////IGMP GROUP ENTRY STATE FOR HOST////  
////////////////////////////////////
```

```
private static final int NONMEMBER=0;//is similar to FREE  
private static final int DELAYING=1;  
private static final int IDLE=2;
```

(2) Constant in PIMDM class

```
////////////////////////////////////
///PIM MESSAGE TYPE/////
////////////////////////////////////

public static final int HELLO=0;
public static final int REGISTER=1;           //PIM-SM
public static final int REGISTRE_STOP=2;      //PIM-SM
public static final int JOIN_PRUNE=3;
public static final int BCOTSRAP=4;          //PIM-SM
public static final int ASSERT=5;
public static final int GRAFT=6;
public static final int GRAFT_ACK=7;
public static final int CANDIDATE_RP_ADVERTISEMENT=8; //PIM-SM
private static final int GENERATION_ID=20;

////////////////////////////////////
///// STATE /////
////////////////////////////////////

public static final int DESIGNATED_ROUTER=0;
public static final int ASSERT_WINNER=1;
public static final int LEAF_ROUTER=2;
private static final int ROUTER=4;
private static final int OLD_ROUTER=5;

////////////////////////////////////
/////PIM-DM GROUP ENTRY STATE FOR HOST/////
////////////////////////////////////

private static final int FREE=0;
private static final int USED=1;
private static final int NEGATIVE_CACHE=2;
private static final int PRUNED=3;
private static final int FORWARD=4;
private static final int FORWARD_ALL=5;
public static final int SG_TABLE=0;
public static final int NEIGHBOR_TABLE=1;

////////////////////////////////////
/////PIM-DM Timer state/////
////////////////////////////////////

private static final int IDLE=0;
private static final int INTERFACE=1;
private static final int ENTRY=2;
private static final int OUTPORT=3;

////////////////////////////////////
/////DEFAULT TIMER AND COUNT VALUE/////
////////////////////////////////////
//scaling factor= 0.2 original value is stated after the "/"
private static double HELLO_TIMER=6; //30
private static double TRIGGERED_HELLO_DELAY=1; //5;
private static double NEIGHBOR_TIMER=3.5*HELLO_TIMER; //105;
```

```

private static double DATA_TIMEOUT_TIMER=42; //210;
private static double PRUNE_TIMER=20; //100;
private static double GRAFT_ACK_TIMER=0.6; //3;
private static double ASSERT_TIMER=36; //180;
private static double ASSERT_OVERRIDE_INTERVAL=0.6; //3;
private static double T_OVERRIDE=0.5; //2.5;

////////////////////////////////////
//////PIM DM EVENT TYPE//////
////////////////////////////////////

public static final int EV_PIMDM_RECEIVE=SimProvider.EV_PRIVATE + 201;
public static final int EV_PIMDM_SEND=SimProvider.EV_PRIVATE + 202;

////////////////////////////////////
//////TIMER EVENT//////
////////////////////////////////////

public static final int EV_HELLO_TIMER =SimProvider.EV_PRIVATE + 203;
public static final int EV_NEIGHBOR_TIMER = SimProvider.EV_PRIVATE +
204;
public static final int EV_DATA_TIMEOUT_TIMER = SimProvider.EV_PRIVATE
+ 205;
public static final int EV_PRUNE_TIMER = SimProvider.EV_PRIVATE + 206;
public static final int EV_GRAFT_ACK_TIMER = SimProvider.EV_PRIVATE +
207;
public static final int EV_ASSERT_TIMER =SimProvider.EV_PRIVATE + 208;
public static final int EV_UNICAST_TABLE_CHANGE=SimProvider.EV_PRIVATE
+ 209;
public static final int GET_OUTGOINGIF=0;

```

Appendix C

Simulation Results For Performance Evaluation

(1) Results of Simulation Test on Join Latency

Results for dense distribution and sparse distribution of multicast membership are presented below.

These results are taken from the event log file. The time for every joining event and first packet received event are recorded. Join latency is obtained by subtracting first packet received time by joining event time.

(a) Dense Distribution of Multicast Membership

Number of Member	10	15	20	25
Join Latency (unit in microsecond)	21338.63	11570.84	21737.32	14320.50
	31622.31	21567.72	12013.25	14320.50
	24032.03	35462.43	21338.63	33653.47
	46259.00	6452.49	23000.23	1209.50
	39337.86	40047.02	6622.09	21228.52
	48658.25	35767.29	41453.52	23000.23
	34613.64	50776.11	7874.78	35462.43
	8953.81	6826.62	26795.90	7907.55
	4126.02	3158.86	36561.56	40352.30
	36954.54	36560.77	41735.52	2144.45
		46802.72	46089.40	46089.40
		11136.40	6657.02	5781.15
		12957.64	24317.85	3328.46
		14401.37	3328.46	18674.48
		34377.68	22611.75	2783.42
			3956.42	44688.93
			31144.27	50932.05
			16886.48	1778.68
			7682.65	10921.55
			9128.49	3786.82
			46726.82	
			7261.41	
			9213.16	
			7513.05	
			14401.37	
Average	29589.61	24524.40	20546.78	18699.21

(b) Sparse Distribution of Multicast Membership

Number of Member	10	15	20	25
Join Latency (unit in microsecond)	21338.63	11570.84	21737.32	14320.50
	31622.31	21567.72	12013.25	14150.90
	24032.03	35462.43	21169.03	33653.47
	6396.40	6452.49	23169.83	1209.50
	46259.00	40047.02	6452.49	23000.23
	48488.65	35597.69	41453.52	35292.83
	34613.64	50776.11	7705.18	7737.95
	8953.81	6657.02	26795.90	5120.87
	4126.02	3158.86	36561.56	40352.30
	36954.54	36730.37	41905.12	2144.45
		46802.72	46089.40	45919.80
		11136.40	6657.02	5781.15
		12957.64	24148.25	3328.46
		14401.37	3328.46	18674.48
		34377.68	22611.75	2953.02
			3956.42	44688.93
			31144.27	50932.05
			16886.48	1778.68
			7682.65	10751.95
			9128.49	3956.42
			46726.82	
			7261.41	
			9213.16	
			7682.65	
			14401.37	
Average	26278.50	24513.09	20529.82	18041.33

(2) Traffic Records of Simulation Test on Link Utilization and Traffic Concentration

These results were obtained from the existing GUI traffic record

Simulation Topology	Average Traffic (%)		Maximum Traffic (%)	
	Peak Value	Long term Value	Peak Value	Long term Value
10 Members Dense Distribution	2.054	0.050	4.24	0.158
15 Members Dense Distribution	2.054	0.053	4.24	0.162
20 Members Dense Distribution	2.054	0.061	4.24	0.160
25 Members Dense Distribution	2.054	0.067	4.24	0.161
10 Members Sparse Distribution	2.054	0.043	4.24	0.155
15 Members Sparse Distribution	2.054	0.045	4.24	0.161
20 Members Sparse Distribution	2.054	0.050	4.24	0.160
25 Members Sparse Distribution	2.054	0.051	4.24	0.163

Traffic concentration was calculated by the formula stated in section 6.3.

Simulation Topology	Traffic Concentration
10 Members Dense Distribution	84.80
15 Members Dense Distribution	80.00
20 Members Dense Distribution	69.51
25 Members Dense Distribution	63.28
10 Members Sparse Distribution	98.60
15 Members Sparse Distribution	94.22
20 Members Sparse Distribution	84.80
25 Members Sparse Distribution	83.14

(3) Result of Simulation Test on Protocol Overhead

Number of messages exchanged in the simulation was recorded in the GUI display for each router.

(a) Dense Distribution of Multicast Membership

Router Name	Protocol Overhead (number of messages)			
	10 members	15 members	20 members	25 members
R1	336	336	320	318
R2	266	266	266	220
R3	332	348	320	338
R4	224	228	212	224
R5	324	326	330	316
R6	446	446	424	442
R7	266	220	249	225
R8	241	248	245	255
R9	266	223	247	239
R10	318	336	320	328
R11	623	598	584	576
R12	626 ¹	619	618	529
R13	513	504	482	490
R14	489	491	489	467
R15	531	525	477	497
R16	473	387	443	397
R17	580	586	574	597
R18	606	603	605	617
R19	780	755	742	690
R20	790	705	711	767
R21	478	595	535	463
R22	468	473	443	475
R23	330	451	443	315
R24	321	370	370	317
Number of link	55	55	55	55
Protocol Overhead Index (message/link)	193.2182	193.4364	189.9818	183.6727

(b) Sparse Distribution of Multicast Membership

Router Name	Protocol Overhead (number of messages)			
	10 members	15 members	20 members	25 members
R1	334	333	314	318
R2	266	266	266	266
R3	328	322	332	318
R4	266	266	266	266
R5	370	370	370	370
R6	432	426	420	420
R7	266	266	266	266
R8	266	266	266	266
R9	266	266	266	266
R10	328	334	324	324
R11	618	605	581	588
R12	626	619	618	620
R13	531	518	536	513
R14	575	574	575	574
R15	500	492	480	480
R16	484	484	484	484
R17	632	634	633	634
R18	633	632	626	629
R19	826	813	796	796
R20	812	757	791	797
R21	484	595	463	472
R22	477	475	463	465
R23	336	451	315	324
R24	326	370	315	318
Number of link	55	55	55	55
Protocol Overhead Index (message/link)	199.6727	202.4364	195.7455	195.8909

Appendix D

Multicast Address Category

Address	Group
224.0.0.0	Reserve
224.0.0.1	ALL-SYSTEM on this SUBNET
224.0.0.2	ALL-ROUTERS on this SUBNET
224.0.0.4	DVMRP-ROUTERS
224.0.0.5	OSPFIGP-ALL-ROUTERS
224.0.0.6	OSPFIGP-Designated-ROUTERS
224.0.0.13	ALL-PIM-ROUTERS