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Gedae: Auto Coding to a Virtual Machine

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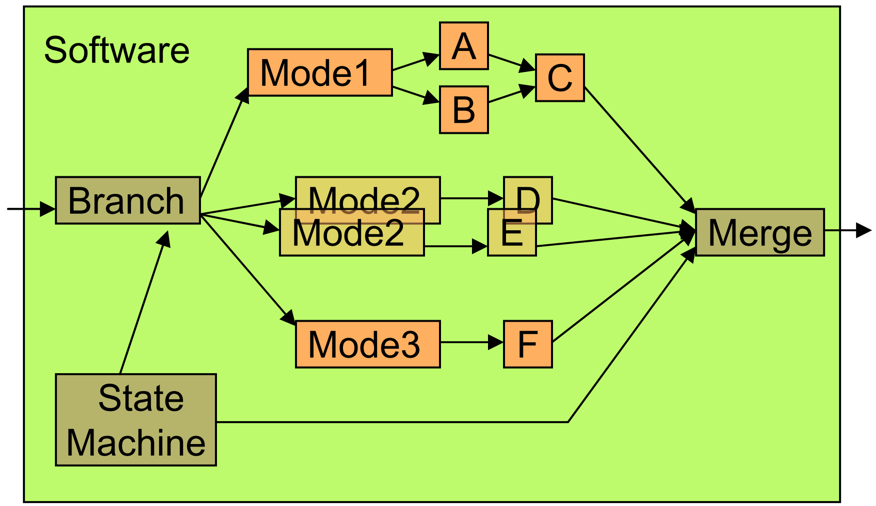
Gedae, Inc.
www.gedae.com

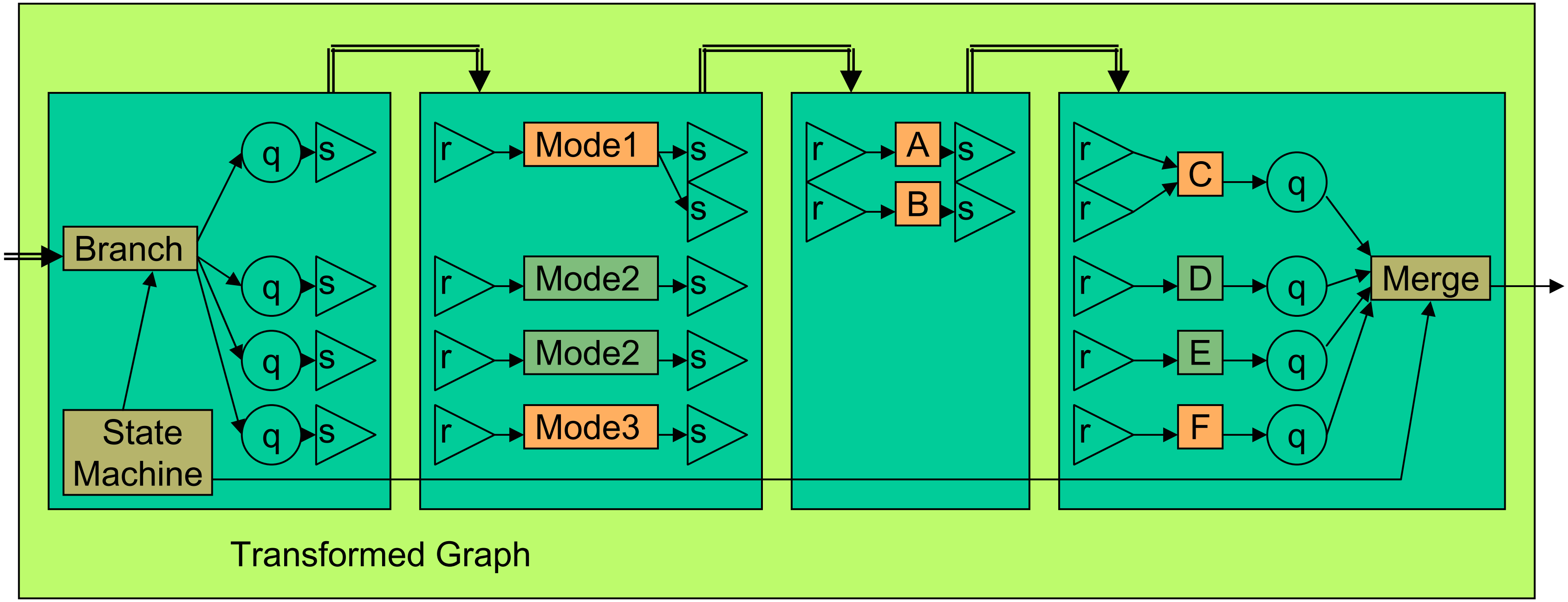
What is Gedae?

Gedae is a block diagram **language** ...



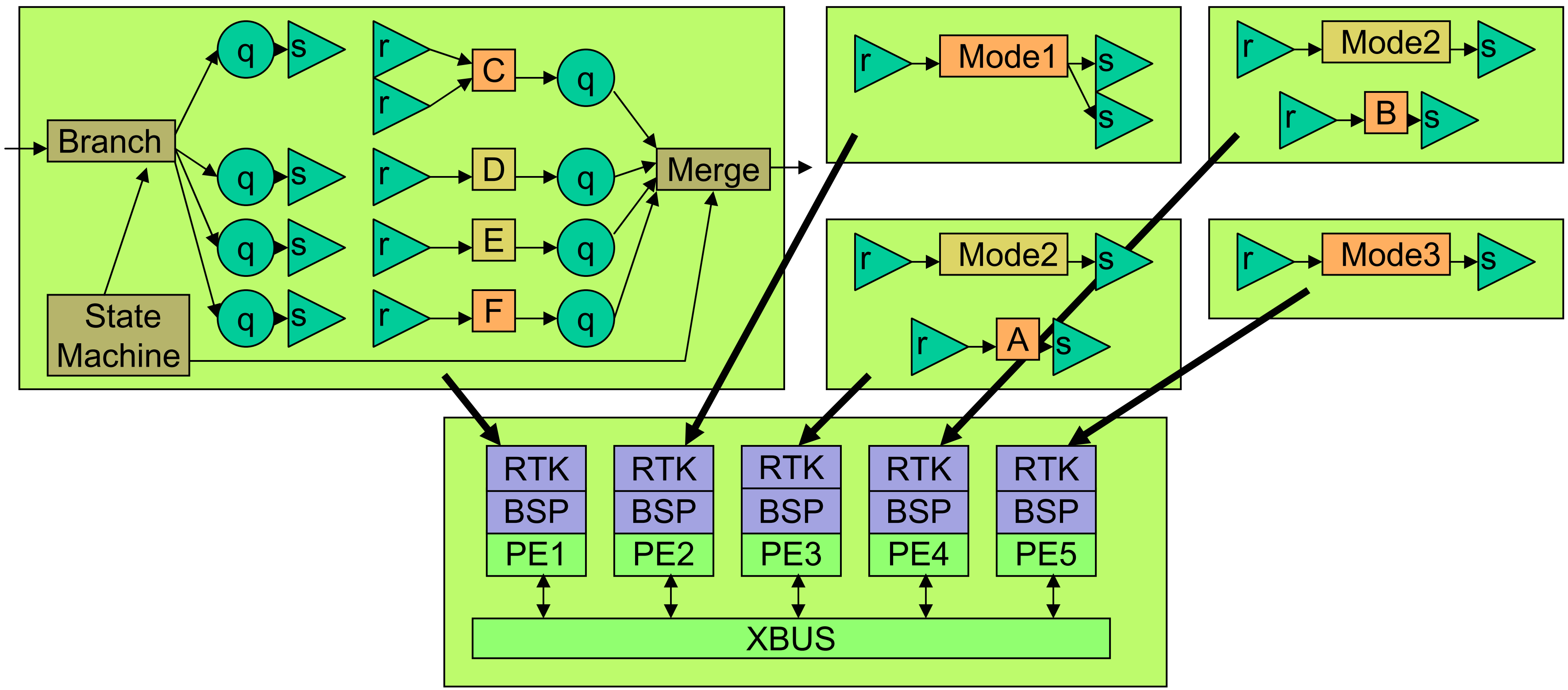
Express signal and data processing algorithms, parallelism, load balancing, fault tolerance and mode control

...that Gedae **transforms** under user control...



User can set optimization parameters that are independent of the graph to guide transformation

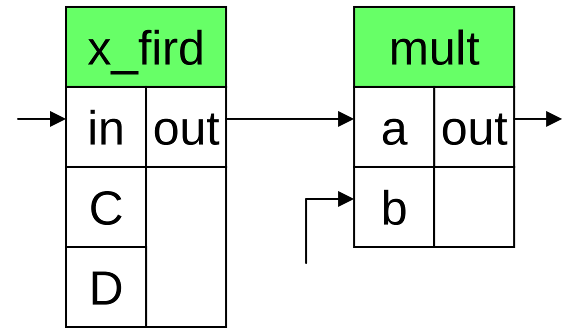
...to operate efficiently on a **virtual machine.**



Complete systems can be developed independent of the target system without losing runtime efficiency

Gedae Language

- Gedae provides application information through
  - modules with well-defined behavior
  - ports with well-defined characteristics
  - and manifest connectivity with explicit sequential and parallel execution paths
- This information is implicit in most languages
- Gedae makes the information explicit
  - over 50 different information expression features




```
stream complex in[N](D);
```

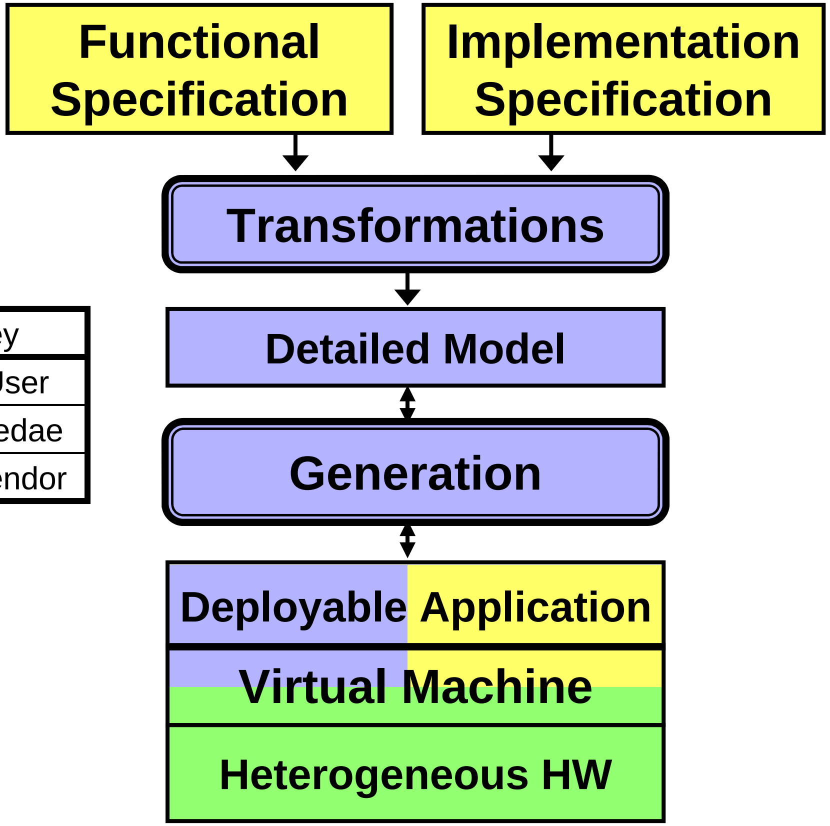
- stream of tokens
- tokens contain complex data
- tokens are a vector with N elements
- box requires D input tokens.

Information provided by language allows Gedae to analyze and efficiently implement algorithms

Gedae Transformations

- The block diagram is transformed using over 100 algorithms.
- The transformations establish the:
  - Order of execution
  - Queue sizes
  - Granularities
  - Memory layout
  - Dynamic schedule parameters
  - Data transfer types and parameters
  - Mode control

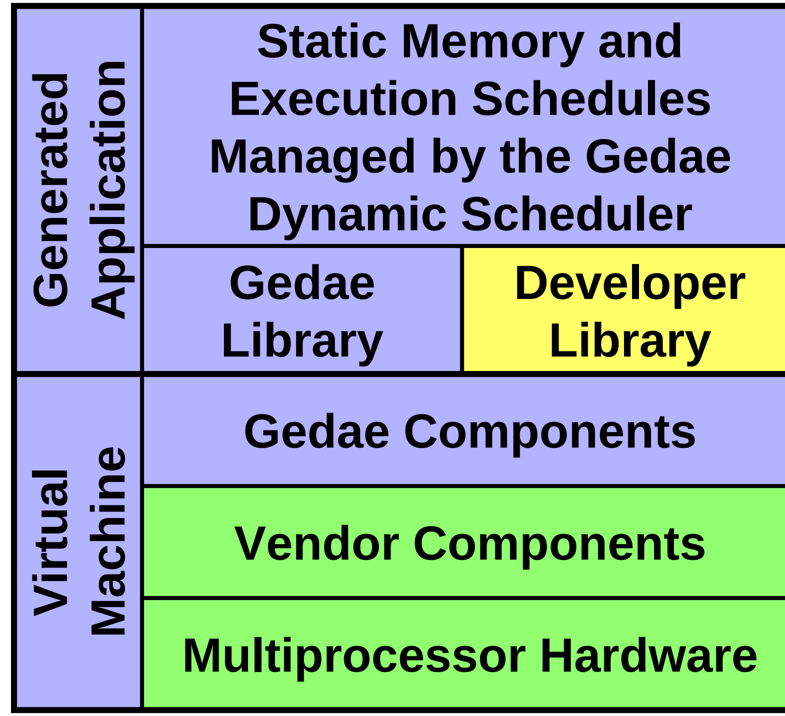
Key	
(yellow)	User
(blue)	Gedae
(green)	Vendor



The Gedae transformations build a detailed model of the deployed application. Gedae uses that information to provide visibility

Gedae Virtual Machine (VM)

- Gedae provides the following components:
  - Command handler
  - Dynamic scheduler
  - Segmentation Support
  - Primitive Support
  - Visibility Support
- The vendor provides
  - Inter-processor communications
  - Optimized vector libraries
  - Other basic services



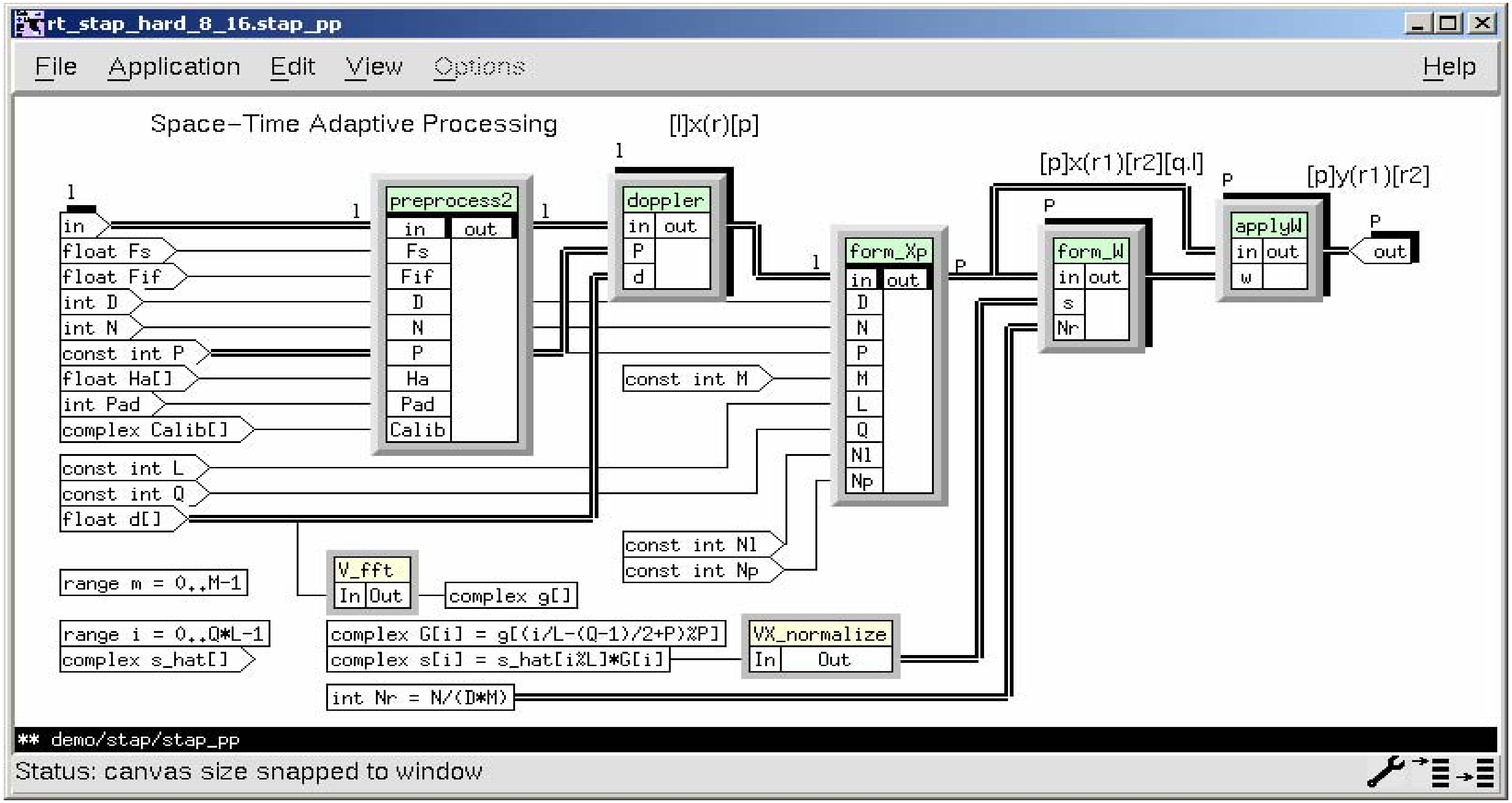
The Gedae virtual machine makes applications processor independent

Three Examples

- Real-Time Space-Time Adaptive Processing (RT-STAP)
  - Miter benchmark graph
  - Illustrates efficient parallel execution of large graph
- Multilevel Mode Graph
  - Illustrates nested mode control with distributed state
  - Dynamic data application
- Sonar Graph
  - Illustrates large data reduction during processing

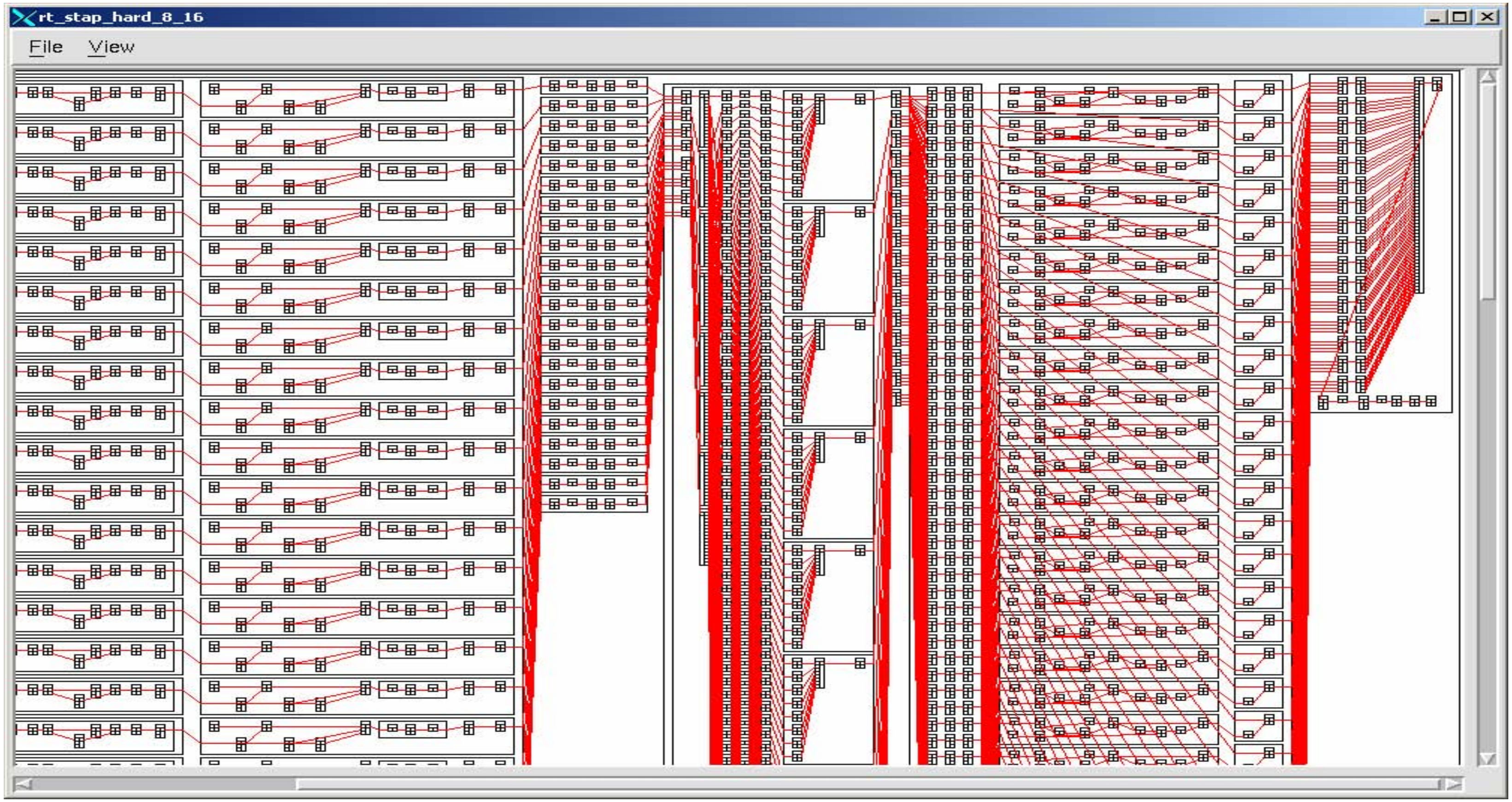
Each example illustrates features of the language, transformations, and virtual machine

RT-STAP: Language



Families permit replicating box and data elements

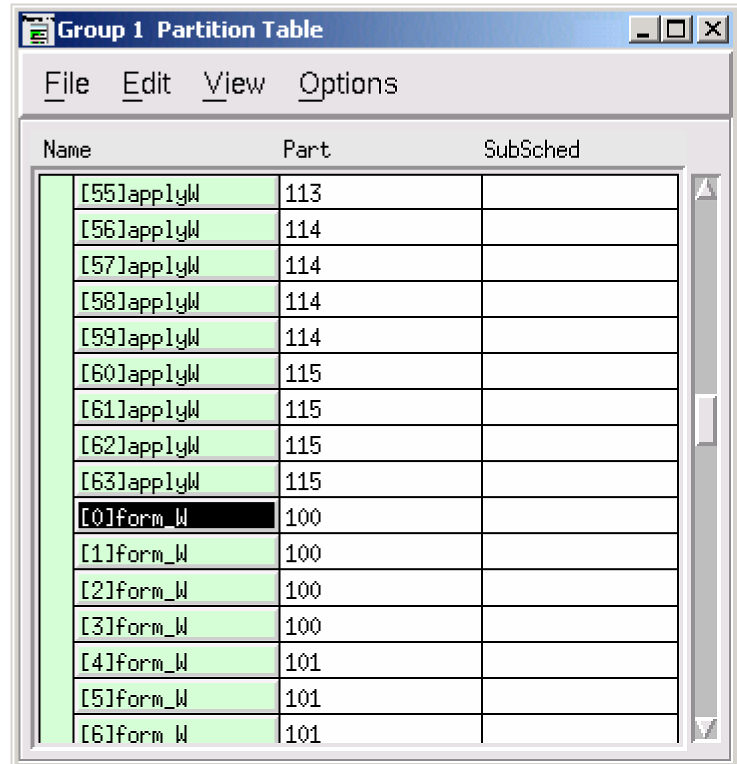
RTS-STAP: Language



- Instantiation constants control the size of the graph
- Routing boxes allow equation based connectivity

RT-STAP: Transformations

- User maps primitives to physical processors
- Gedae transforms graph by inserting send/receive primitives to communicate between partitions
- Gedae automatically creates executables to run on each processor



Name	Part	SubSched
[55]applyW	113	
[56]applyW	114	
[57]applyW	114	
[58]applyW	114	
[59]applyW	114	
[60]applyW	115	
[61]applyW	115	
[62]applyW	115	
[63]applyW	115	
[0]form_W	100	
[1]form_W	100	
[2]form_W	100	
[3]form_W	100	
[4]form_W	101	
[5]form_W	101	
[6]form_W	101	

Different mappings can be tried without modifying the graph – the needed transformation happens automatically

RT-STAP Transformations

- User can set transfer properties on send/recv pairs with Transfer Table
- Transformations automatically set parameters to send/recv pairs to communicate these properties to running application

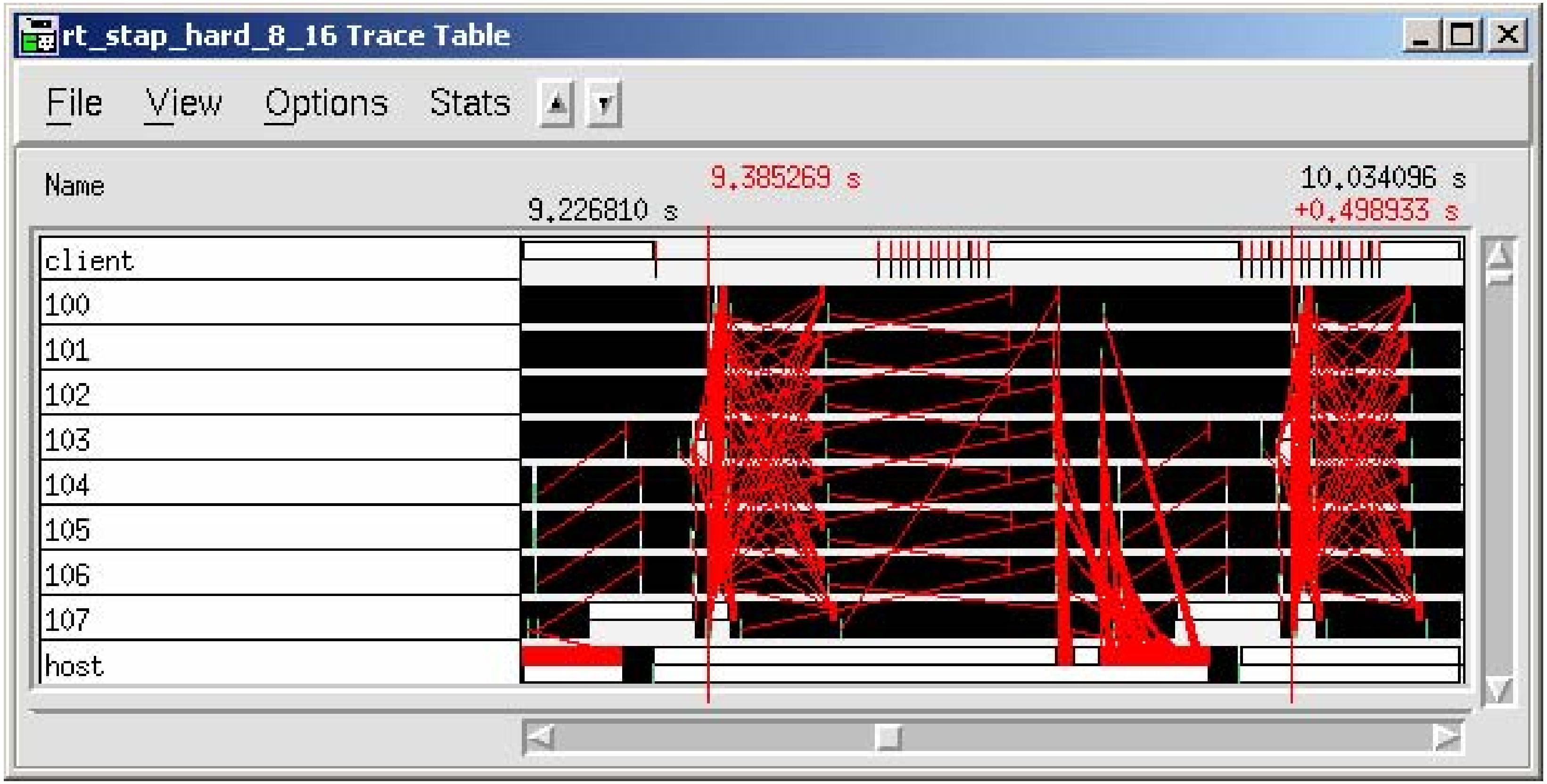
Group 1 Transfer Table

File Edit View Options Help

Name	Source	Dest	Xfer Type	NBsize	Send Bufs	Recv Bufs	Xfer Params
stap_pp.form_Xp.corner_t.[0][13]mx_vx_1<in	116	113	stream	46080			-b 10 -d 2
stap_pp.form_Xp.corner_t.[7][14]mx_vx_1<in	123	114	dsa		2	3	-b 10 -d 2
stap_pp.form_Xp.corner_t.[6][14]mx_vx_1<in	122	114	dsa		2	3	-b 10 -d 2
stap_pp.form_Xp.corner_t.[5][14]mx_vx_1<in	121	114	dsa		2	3	-b 10 -d 2
stap_pp.form_Xp.corner_t.[4][14]mx_vx_1<in	120	114	dsa		1	1	
stap_pp.form_Xp.corner_t.[3][14]mx_vx_1<in	119	114	stream	46080			
stap_pp.form_Xp.corner_t.[1][15]mx_vx_1<in	117	115	stream	46080			
stap_pp.form_Xp.corner_t.[0][15]mx_vx_1<in	116	115	stream	46080			
stap_pp.form_Xp.[0]rfam_mx<[0]in	115	100	stream	84480			
stap_pp.preprocess2.[20]iq_convert2.v_mult0sc<in	124	123	dsa		1	1	
stap_pp.preprocess2.[21]iq_convert2.v_mult0sc<in	124	123	dsa		1	1	
sink_pp.[0]vx_mux<[0]in	100	host	gsim_host>host	3840			
sink_pp.[0]vx_mux<[1]in	100	host	gsim_host>host	3840			

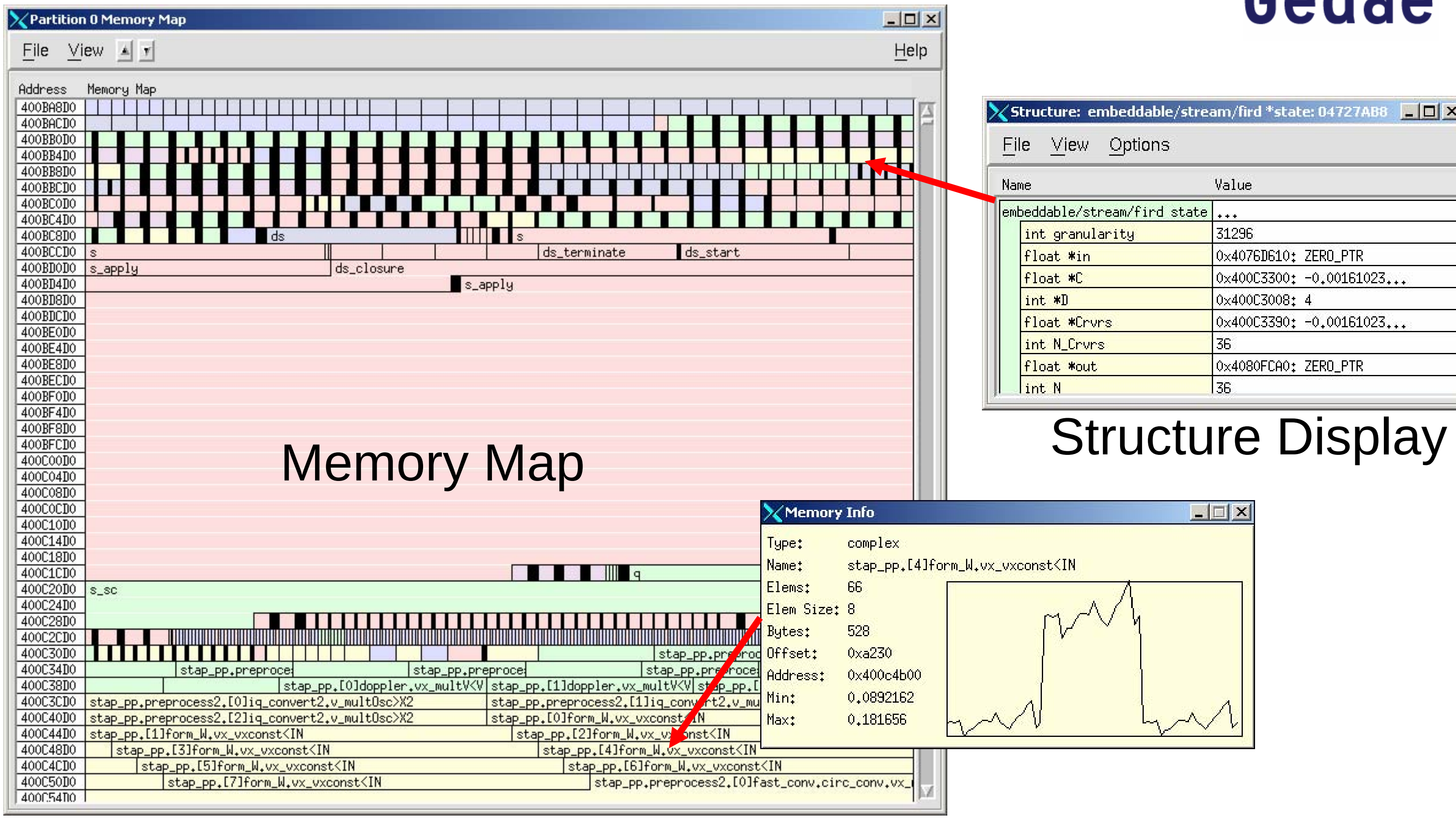
User can guide transformations to optimize implementation

RT-STAP: Running on VM



Send/Recv webs show interprocessor communication and uncover synchronization problems

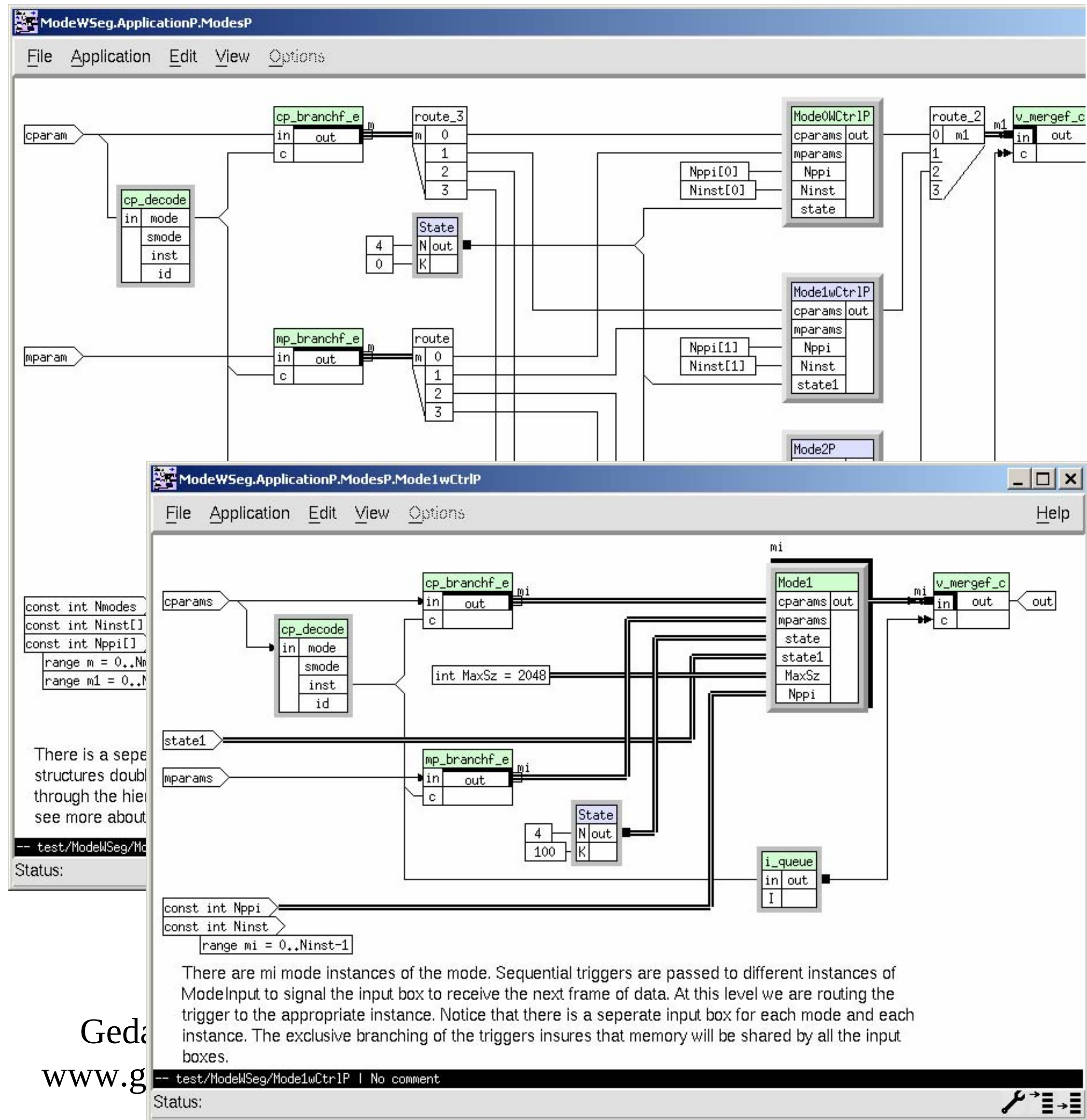
RT-STAP: Running on VM



Preplanned use of memory allows distributed runtime debugging

Mode Control: Language

- Branch boxes make mode changes and mark segment boundaries
- “Exclusive” branch outputs show where resources can be shared
- State shared between modes is explicitly declared in the graph



The Gedae primitive language directly supports segmented data processing, sharing of resources, and distribution of state

Mode Control: Language

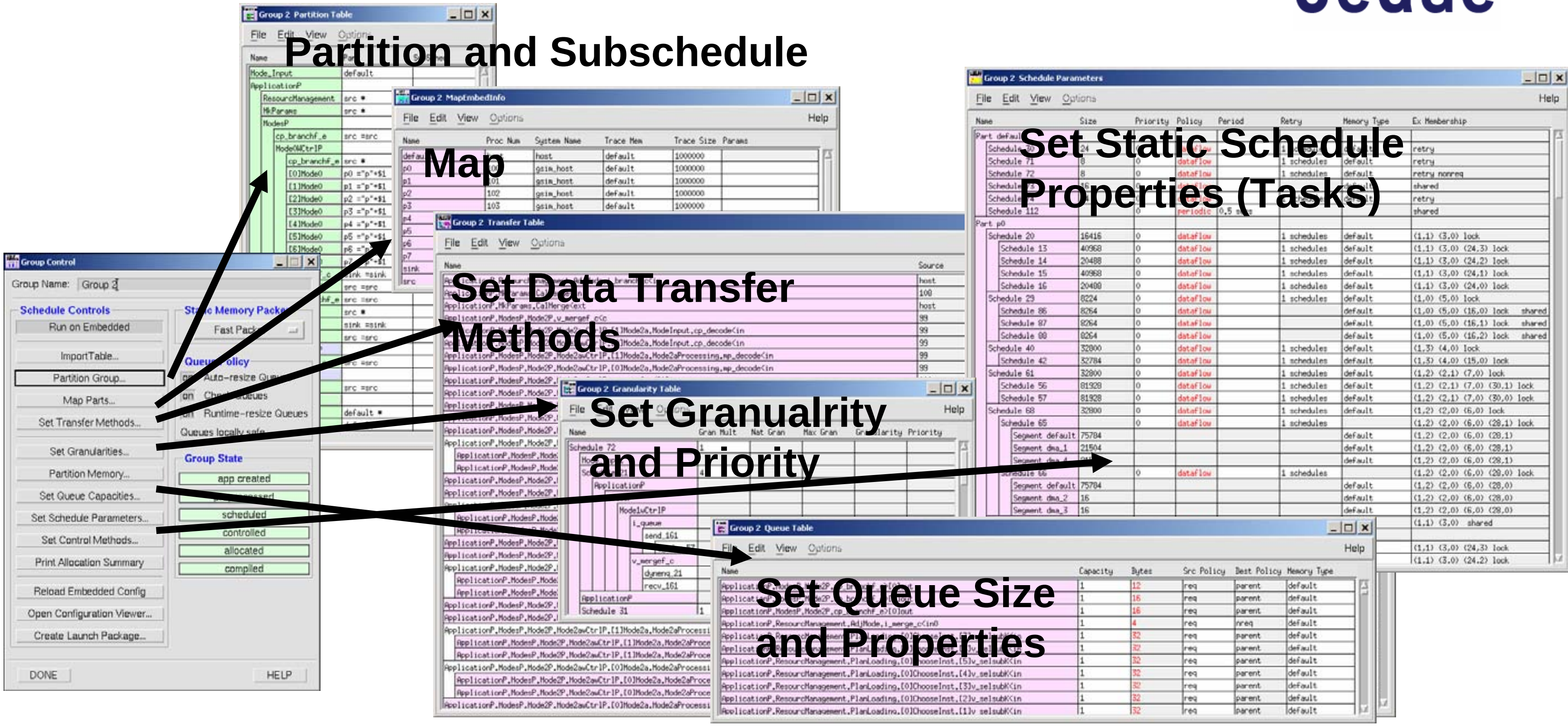
Branch box copies input data stream to one of a family of outputs based on a control stream. Output is:

- **Segmented** - the box will add **segment** boundaries to the output
- **Dynamic** - the box will state how much data is **produced** on the output at runtime.
- **Exclusive** - only one of the family of F outputs gets data on any firing. Allows sharing of resources and state.

The Gedae extensible language has no “built-in” primitives. 8000+ delivered primitives. Users can add custom primitives

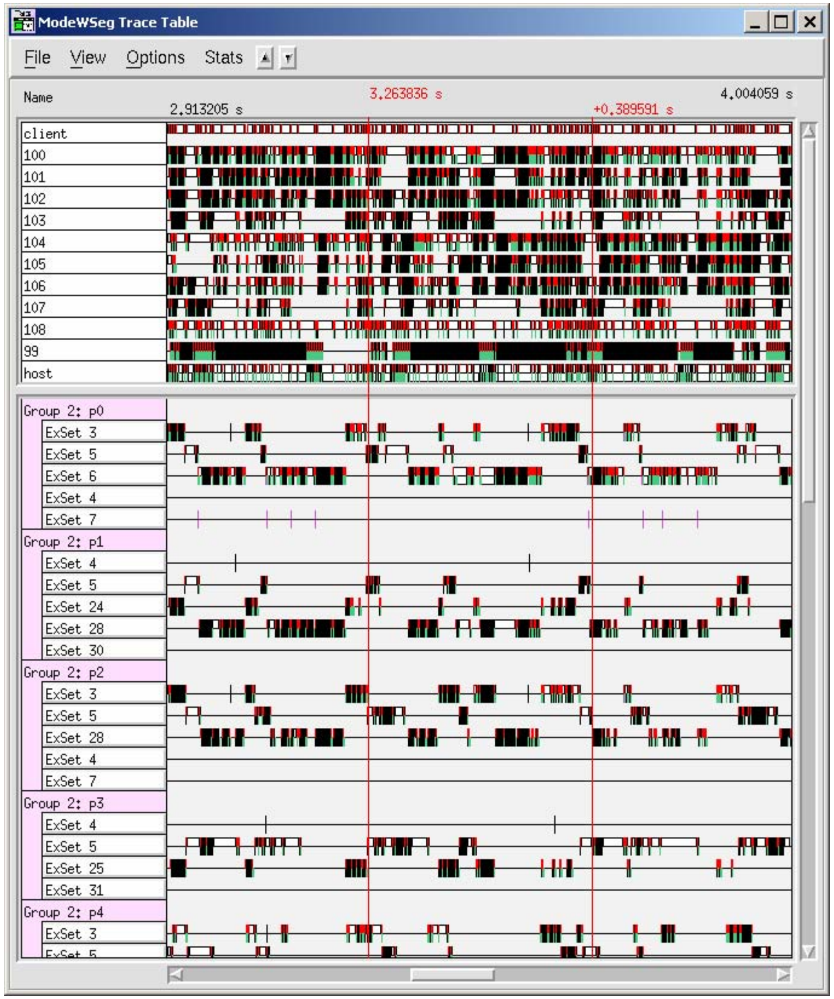
```
Name: cp_branchf_e
Input:  stream ControlParamRec in;
Input:  stream int c;
Local:  int last;
Output: exclusive segmented dynamic stream
        ControlParamRec [F]out;
Reset: { last = -1; }
Apply: {
  int g,i;
  int prdc = 0;
  for (g=0; g<granularity; g++) {
    int j = c[g];
    if (last != j) {
      if (0<=last && last<F) {
        produce(out[last],prdc);
        prdc = 0;
        segment(out[last],SEGMENT_END);
      }
      last = j;
    }
    if (0<=j && j<F) {
      *out++ = *in;
      prdc++;
    }
    in++;
  }
  produce(out[last],prdc);
}
```

Mode Graph: Transformation



User can set partitioning, mapping, data transfer methods, granularity, priority, queue sizes and schedule properties from the group control dialog

Mode Graph: Running on VM

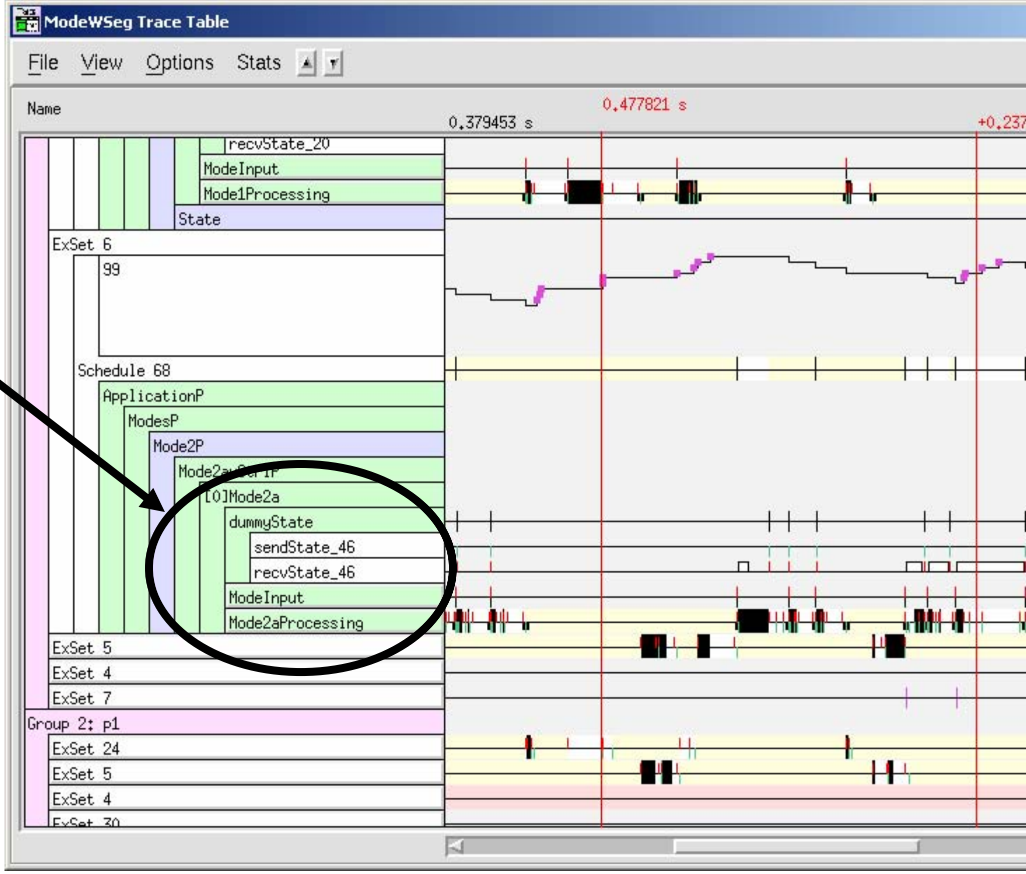


- Each mode requires a different number of processors
- Branch boxes at one level are responsible for the dynamic distribution

VM runtime kernel enforces dynamic data driven execution. Send and receive primitives and state transfer primitives use BSP of virtual machine to transfer data

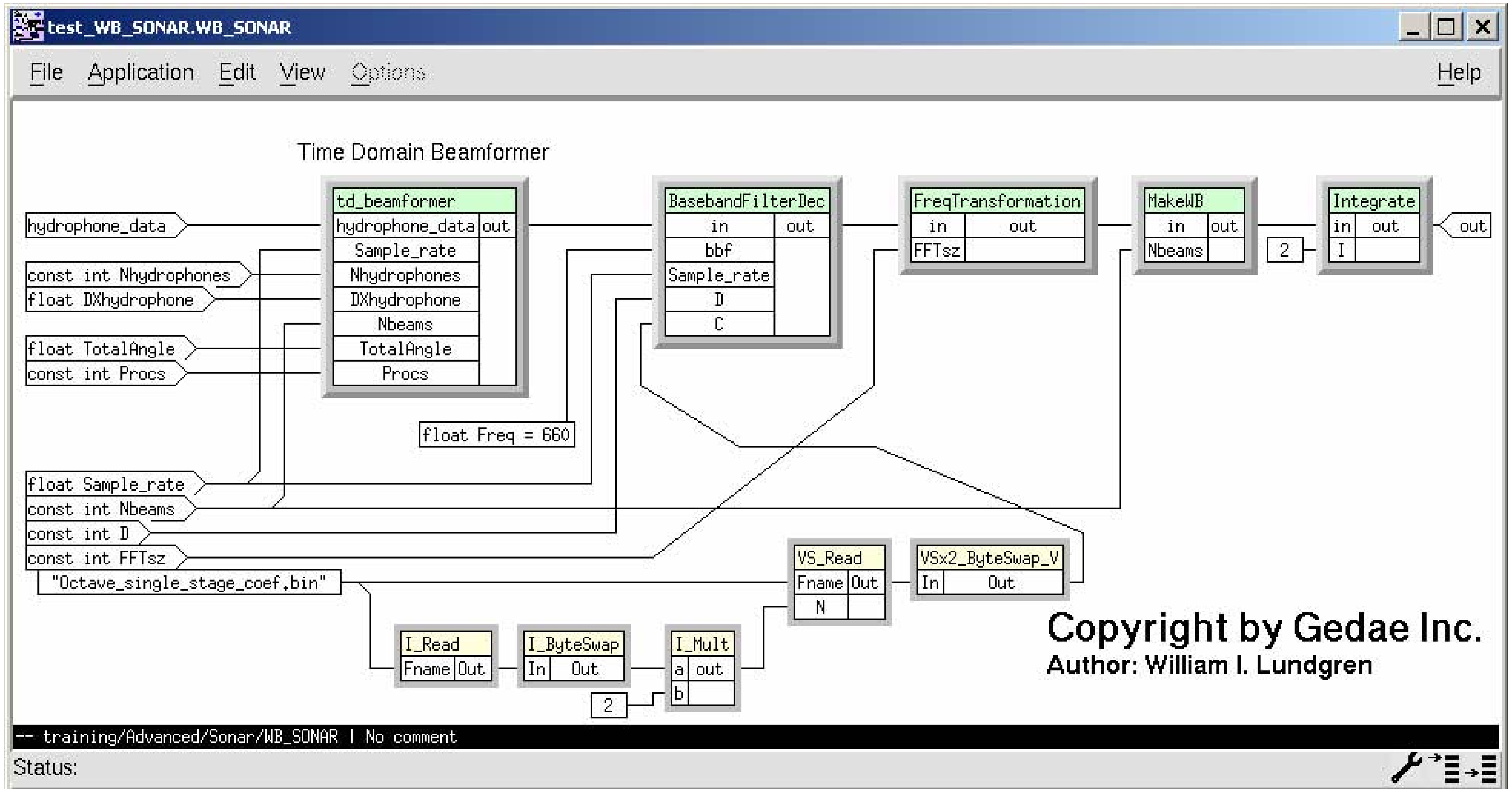
Mode Graph: Running on VM

- Primitives to send and receive state are automatically added by transformations
- Messages generated by Virtual Machine at mode change boundaries efficiently coordinate state transfers



Result is efficient transparent use of shared state on distributed processing system

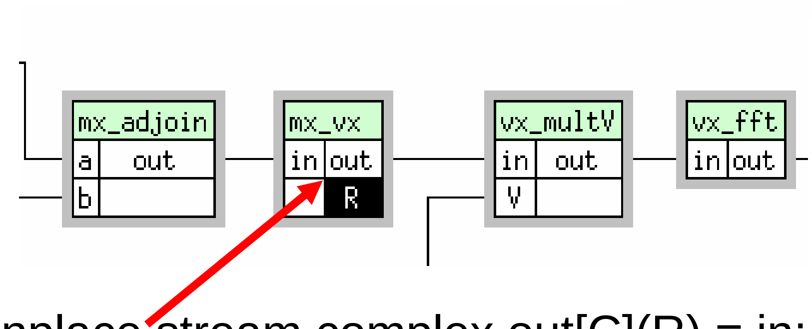
Sonar: Language



Sonar Graph creates low bandwidth output from high bandwidth input data

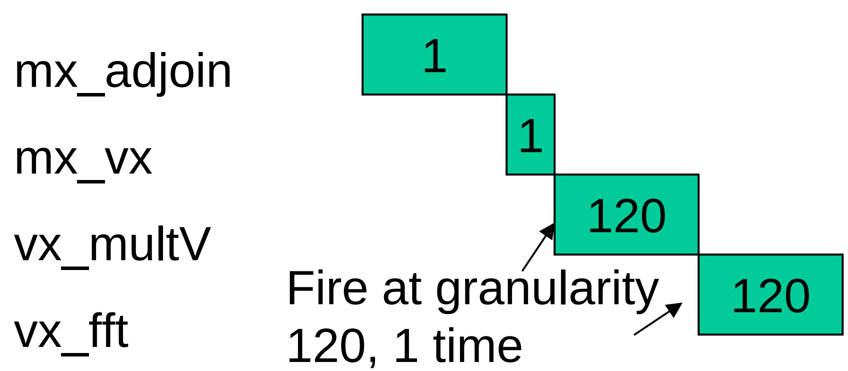
Sonar: Language

- Connectivity + Port Descriptions gives information needed to schedule graph
- mx_vx produces R=120 tokens out for every 1 token in
- vx_multV box must fire 120 times for each firing of the mx_vx box.
- vx_fft box fires one time for each firing of vx_multV box
- Simple predetermined schedule generated from graph and info embedded in primitives



inplace stream complex out[C](R) = in;

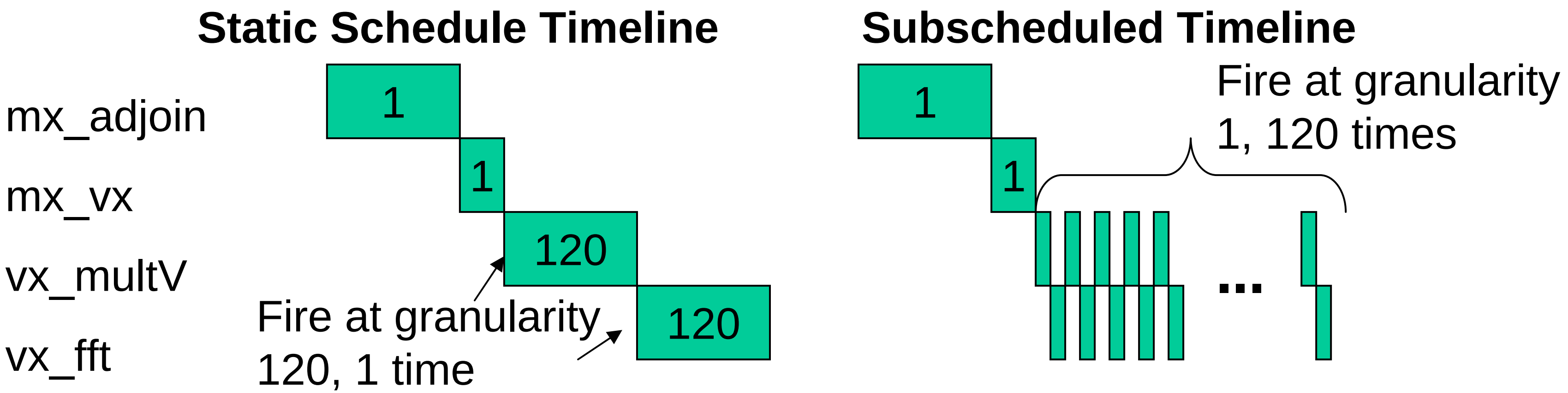
Static Schedule Timeline



Can create a multirate graph that has boxes firing at different granularities

Sonar: Transformation

- User can place boxes in subschedules to strip-mine the vector processing
- Allows use of fast memory
- Can reduce memory usage



Multirate graphs can be implemented using subscheduling to improve speed and reduce memory usage

Sonar: Transformation

Gedae

Auto-Subscheduling Tool

Group 1 Gain Hier Table

File Edit View Options Help

Name	TotalG	Bytes	Div	TDiv	G	Bytes*G	Boxes	Subsched
Schedule 1	1	1440	1	1	1	1440	6	
1	2	1966080	2	2	1	1966080	2	1
2	240	20484	30	60	4	81936	6	1.1
3	1024	4800	32	64	16	76800	1	1.2
4	4096	63628	64	4096	1	63628	17	1.2.1

Schedule Information Dialog

Group 1 Schedule Parameters

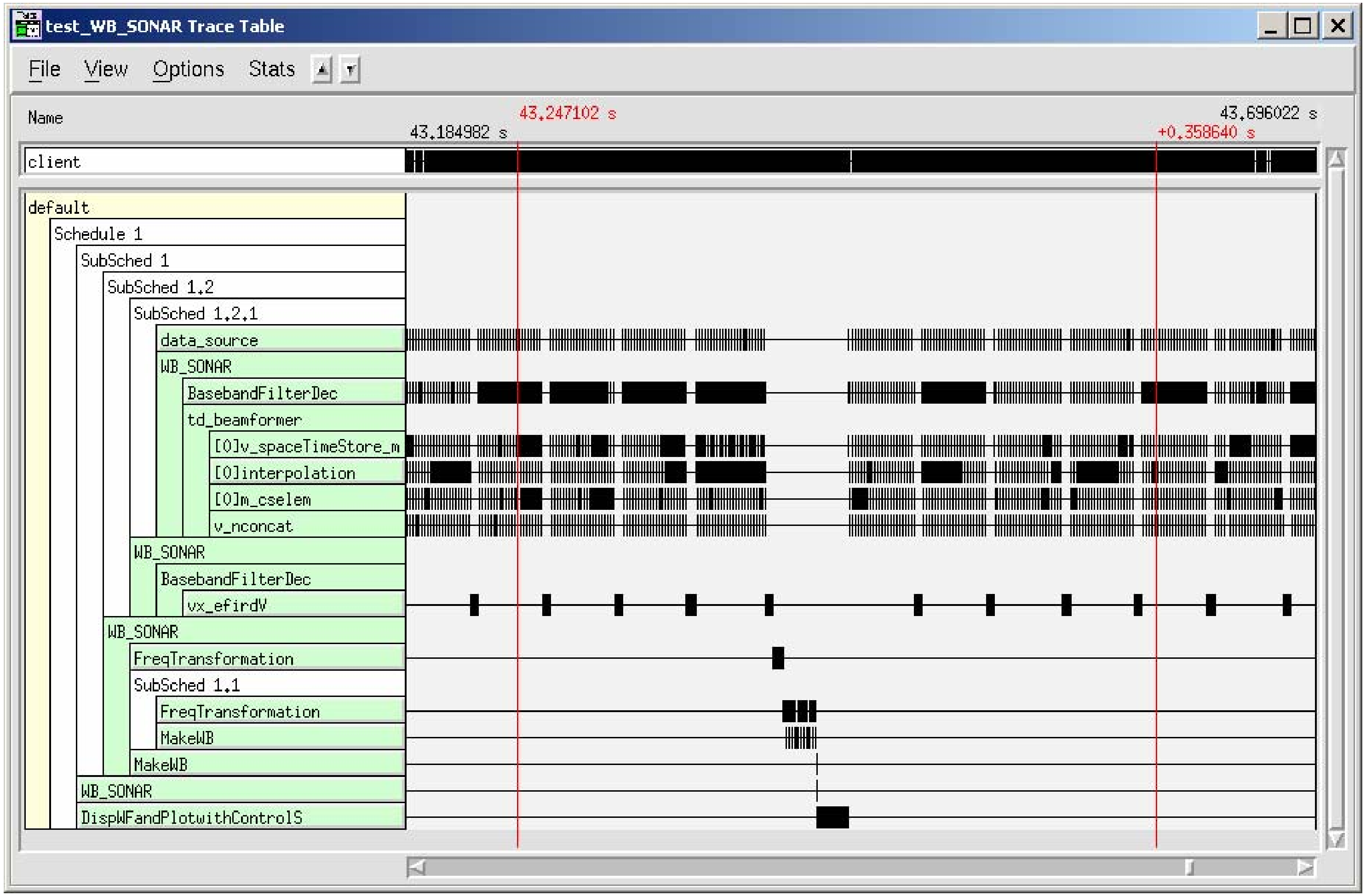
File Edit View Options

Name	Size	Priority	Policy	Peri
Part default				
Schedule 1	1448	0	dataflow	
SubSched 1				
Segment default	2457600			
Segment parent_memory	480			
SubSched 1.1				
Segment default	65536			
Segment parent_memory	32784			
SubSched 1.2				
Segment default	143040			
Segment parent_memory	15360			
SubSched 1.2.1				
Segment default	61720			
Segment parent_memory	960			

- User can put boxes into named subschedules manually – but can be difficult
- Auto-Subscheduling Tool puts boxes in subschedules automatically
- Finds nested sets of connected boxes running at common granularities.
- Automatically sets subscheduling levels

Auto-subscheduling has reduced memory needed by graph from 250 Mbytes to about 2.5 Mbytes - 100x improvement

Sonar: Running on VM



Multiple levels of subscheduling evident on Trace Table

Conclusion

- Gedae Block Diagram Language allows simple expression of a wide range of algorithms
- User optimization information can be added without modifying block diagram
- 100+ transformations create efficient executable application from language and user information
- Application runs efficiently on Virtual Machine
- VM provides portability and visibility