July 23

High Availability through Distributed Control

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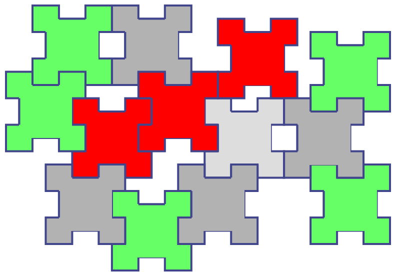
Overview



- Harness: Concept, research areas and architecture.
- Highly available distributed virtual machine (DVM).
- High availability through distributed control.
- Peer-to-peer distributed control algorithm.
- Group communication: Reliable/Atomic Broadcast.
- Fault-tolerant group membership management.
- What we have learned, what next and why?

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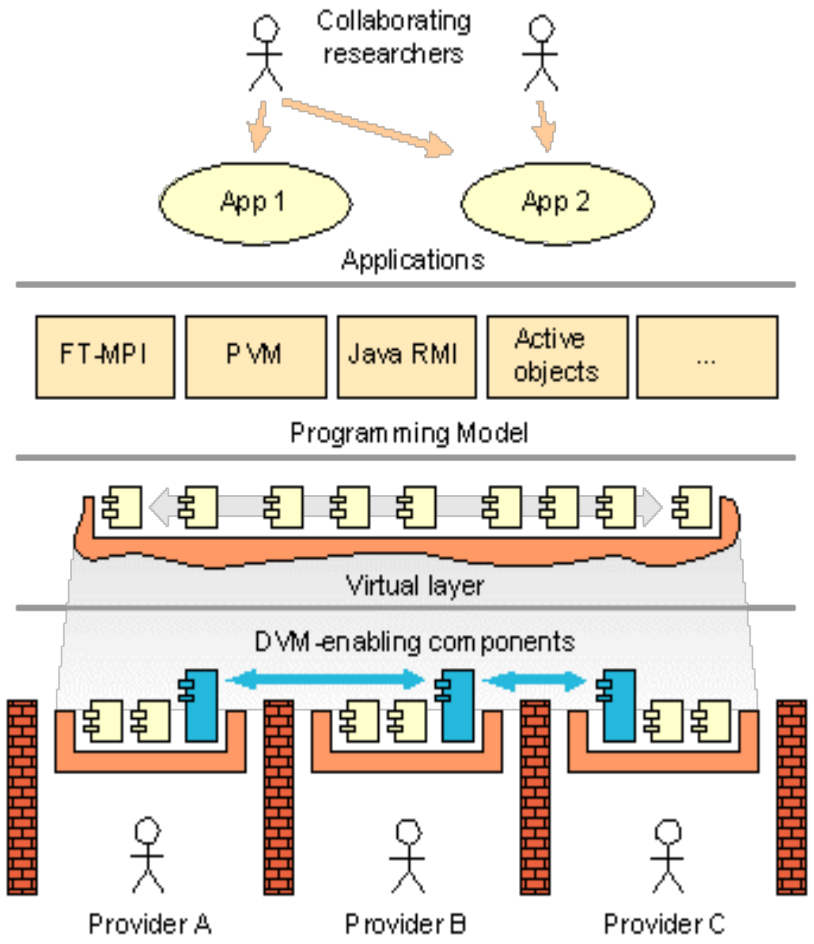
What is Harness

- A pluggable, reconfigurable, adaptive framework for heterogeneous distributed computing.
- Allows aggregation of resources into high-capacity distributed virtual machines.
- Provides runtime customization of computing environment to suit applications needs.
- Enables dynamic assembly of scientific applications from (third party) plug-ins.
- Offers highly available distributed virtual machines through distributed control.
- Various experiments and prototypes (C/Java).

Harness Research Areas

- Lightweight, pluggable software frameworks.
- Adaptive, reconfigurable runtime environments.
- Parallel plug-ins and diverse programming paradigms.
- Highly available distributed virtual machines (DVMs).
- Advanced ultra-scale approaches for fault tolerance.
- Fault-tolerant message passing (FT-MPI).
- Mechanisms for configurable security levels.
- Dynamic, heterogeneous, reconfigurable communication frameworks (RMIX).

Harness Architecture

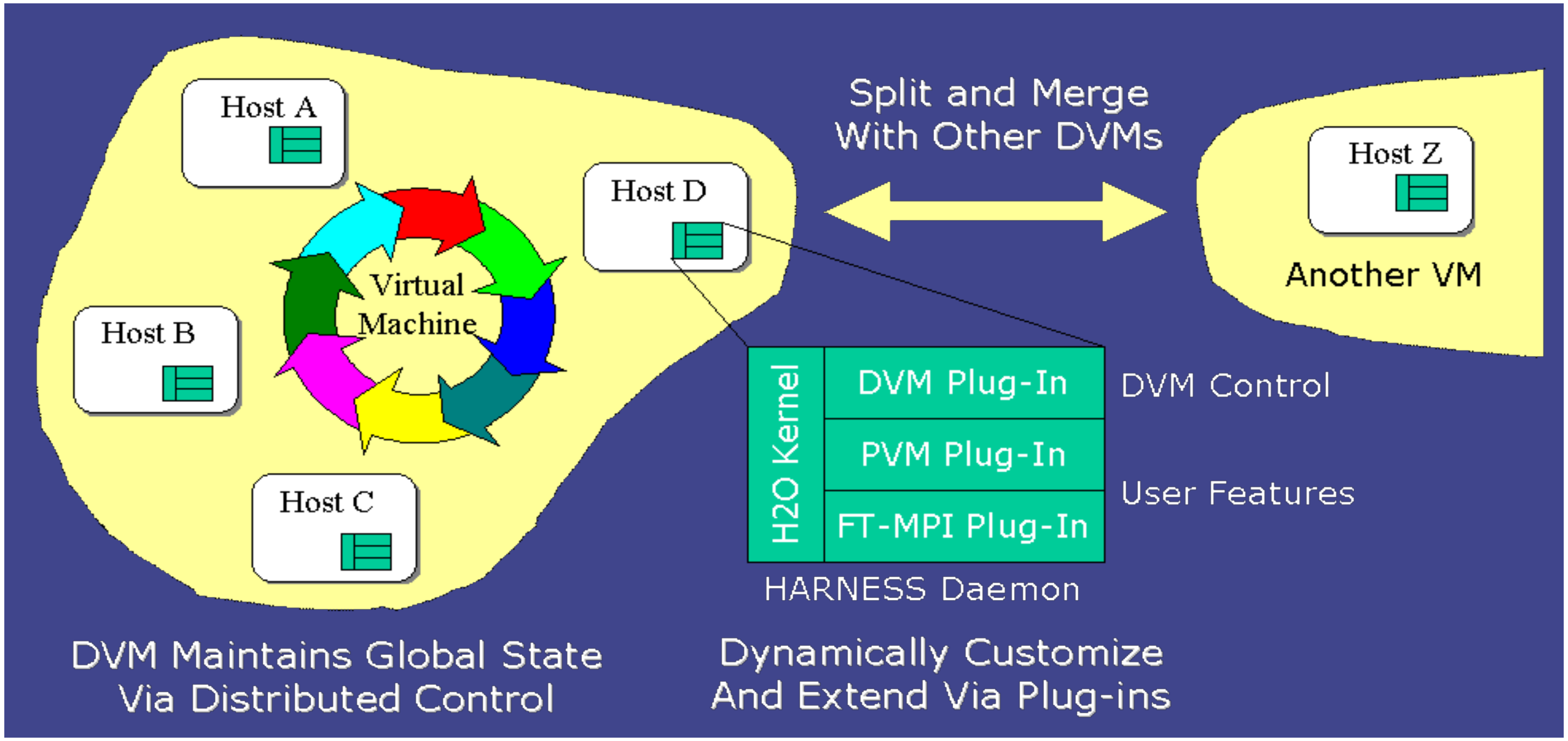


- Light-weight kernels share their resources.
- Plug-ins offer services.
- Support for diverse programming models.
- DVM-enabling plug-ins provide a virtual layer.
- Highly available DVM using distributed control.
- Highly available plug-in services via DVM.

Highly Available DVM

- Parallel virtual machine (PVM).
  - Every node runs a virtual machine (VM).
  - The set of VMs is controlled by a master.
  - The master is a single point of control and failure.
- Distributed virtual machine (DVM).
  - All nodes form a single distributed virtual machine.
  - They equally control the DVM in virtual synchrony.
  - Symmetric state replication assures high availability.
  - No single point of control or failure.
  - The DVM survives while at least one is still alive.

DVM Architecture

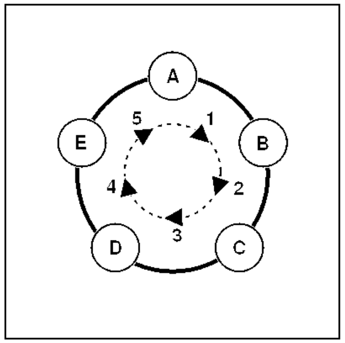


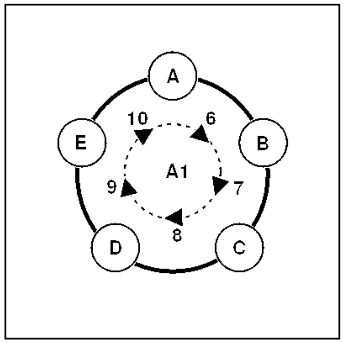
Distributed Control

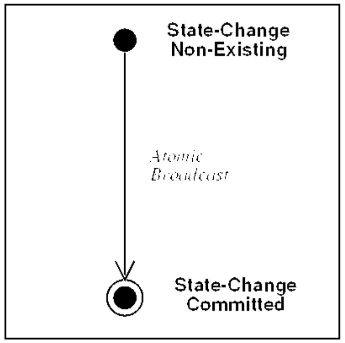
- Steers processes like one virtual process.
- Allows each to have its own independent state.
- Local states form a global virtual process state.
- Mutual exclusive state changes for virtual synchrony.
- Symmetric global state replication for high availability.
- Various abstraction models:
  - Distributed shared memory.
  - Distributed locking of state database.
  - ✓ Less synchronized peer-to-peer mechanisms.
  - Asynchronous distributed agreement (equilibrium).

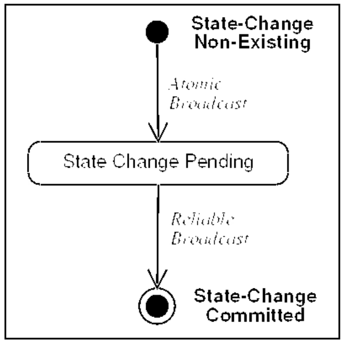
Peer-to-Peer Distributed Control

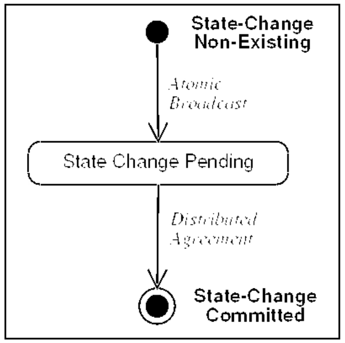
- Unidirectional TCP/IP peer-to-peer ring network.
- Message broadcast is completed after one round.
- Acknowledgement round for Reliable Broadcast.
- Message numbering to achieve Atomic Broadcast.
- Collective communication for Distributed Agreement.
- State change type depends on execution target.











Group Membership Management

- Members agree on an initial state:
  - Every new ring node adopts the current state.
- Members maintain a linear history of state changes:
  - Atomic Broadcast of state changes.
  - Distributed Agreement on execution results.
  - State change commit depending on final result.
- Fault tolerance - Members maintain correctness:
  - Faulty ring nodes are immediately removed.
  - Healthy ring node neighbors reconnect the ring.
  - Possibly lost messages are sent again.

What We Have Learned

- Many other past and ongoing research in group communication and distributed virtual processes exist.
- Main focus is mostly on specific applications and/or communication technologies (e.g. TCP/IP in Harness).
- Most solutions are embedded in applications, part of inflexible middleware or pure communication layers.
- It is still very hard to implement distributed control.
- It is even harder to enable any application or system service to take advantage of high availability.
- Implementations very often "reinvent the wheel".

What Next and Why

- A modular, configurable, light-weight framework can provide more flexible support for different:
  - Abstraction models.
  - Distributed control algorithms.
  - Data replication algorithms.
  - Communication technologies (like in Open MPI).
- Framework goes beyond pluggable protocols.
- A common API can reflect all abstraction models.
- Existing solutions can be put into pluggable modules.
- Enables collaboration of different research groups.

What Next and Why

- High availability services as part of the OS.
- Support for multiple head or service nodes with active/active or active/hot-standby high availability.
- Support for highly available system services, such as:
  - Message passing (e.g. MCA layer of Open MPI).
  - Job schedulers.
  - Parallel file systems.
- Support for highly available scientific applications.
  - For quick response times: earthquake prediction.
  - For long running times: global climate models.

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Questions or Comments?

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