Porting Dyninst to VxWorks

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Dyninst

VxWorks OS Overview

- General properties
  - Designed for embedded systems
  - Hard real-time scheduler
  - Fully preemptive kernel
- Wide range of deployed environments
  - Simple embedded systems
    - Consumer hardware
      - Linksys routers
  - Scientific research equipment
    - Aerospace robotics
      - NASA JPL's Mars rovers

Dyninst

VxWorks OS Overview

- Architecture support
  - 68K/CPU32, ARM, ColdFire, i960, MIPS, PowerPC, SH, SPARC, x86/Pentium/IA-32, XScale
  - We target PowerPC for the port
- Highly configurable kernel
  - Optional components
    - Interactive shell
    - File system
    - Virtual memory

VxWorks Memory Model

- Like UNIX
  - Individual address space for each process
    - Executable data, stacks, heap, etc.
  - Multiple processes can exist in memory simultaneously
- Unlike UNIX
  - Processes do not overlap in virtual memory
  - Advantageous for:
    - Context switching
    - Debugging
    - Cross platform development

VxWorks Applications

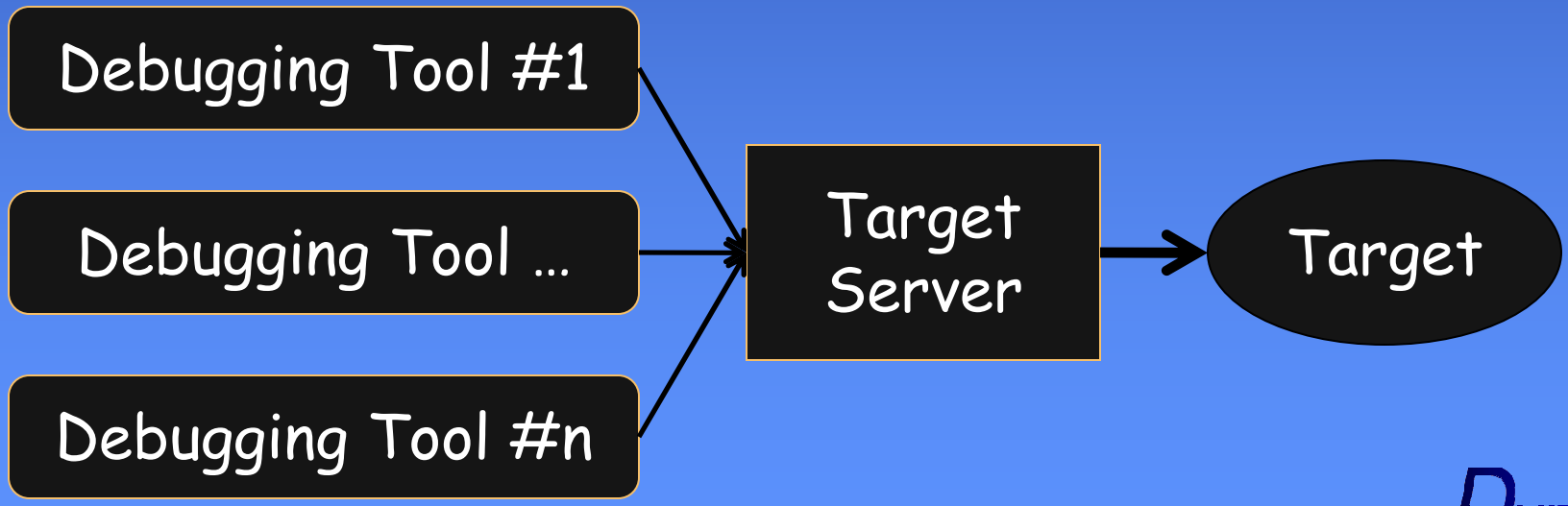
- Real-time process
  - Full POSIX support except
    - No mmap()
    - No process creation via fork() and exec()
    - No file ownership
- Kernel Based
  - Simply another task launched under the kernel
  - No protection from misbehaving application
  - The norm, according to initial research
- Basic execution unit: Task

VxWorks Development

- Separate development from runtime
  - Cross compiler on "host" machine
  - Upload binary and execute on "target" machine
- Debugging must involve both systems
  - Functionality provided by Target Agent (target)
  - Physical link managed by Target Server (host)
    - Ethernet, serial, USB, etc.
    - Modular to provide for future

VxWorks Debugging

- One more level of indirection introduced
  - Allows for flexible connection to target
  - Reduction of communication overhead
    - Kernel binary stored in memory
    - Can return cached results to multiple tools



Dyninst

Target Agent

- Compile kernel with target agent
  - Akin to compiling with debug information
- Basic debugging features
  - Reading/writing task registers
  - Reading/writing process memory
  - Event callback system
    - Task creation/deletion
    - Breakpoints
    - Watchpoints
  - Cache flush/invalidate

Target Agent

- Advanced features
  - Loading/launching RTP/kernel tasks
  - Memory disassembler
  - Target function call
  - Symbol query system
    - Includes adding and removing symbols
    - In core memory only
  - Loading modules from host
    - Kernel or real-time process

WTX Protocol

- Protocol for debugging tools
  - Used to send requests to Target Server
- User friendly libraries for 3rd party use
  - C interface libraries provided
  - Integrate easily with modular design of Dyninst
- Allows any Dyninst platform to be a host
  - WTX libraries must exist on platform

Porting Challenges

- Limited resources
  - VxWorks designed for embedded systems
    - Minimum 1 MB RAM
    - 4MB is encouraged
  - libsymtabAPI.so alone is 1.5MB
  - Where should our runtime library go?
- Solution
  - Leverage Target Agent for all functionality
    - Already required for debugging
  - All other processing can be done on host

Porting Challenges

- No file system
  - Nothing extra on the target system
  - No wealth of libraries for dynamic functionality
    - Applications fully-linked when compiled
- Solution
  - Load everything needed via WTX
    - Including dynamic loader if needed
  - Limited resources may be problematic

Porting Challenges

- WTX Protocol functionality gaps
  - Conspicuous lack of "ps" functionality
  - Cannot perform attach
- Solution
  - Write custom kernel module
    - Module with ps functionality: 3Kb
  - Force target to load module and return data
- Problems
  - Unsure of size restrictions on kernel module
    - 3Kb may still be too big

Porting Challenges

- Incorrect or incomplete symbol info

```
findSym grid*
 Name: gridPrint       Value: 0x18035f8 Size: 0
 Name: gridIsBallAt    Value: 0x1803ae0 Size: 0
 Name: gridInit        Value: 0x18036bc Size: 0
 Name: gridDeleteBall Value: 0x18038fc Size: 0
 Name: gridAddBall     Value: 0x1803858 Size: 0
 Name: grid            Value: 0x0706780 Size: 0
```

- Solution
  - Supplement WTX routines with SymtabAPI
    - Run on host to save target resources

Dyninst

Current Status

- WTX functionality fully investigated
- Parsing VxWorks Binary
  - Kernel and executables use ELF
- Loading task for debugging
  - processCreate() functionality working
  - processAttach() functionality working
- Task instrumentation successful
  - Kernel and RTP tasks tested and working

Future Work

- Move remaining functionality into Dyninst
  - Mostly involves wrapping WTX library calls
- Investigate latency of WTX
  - Mutator effectively 2 indirections away
    - Worse if using a serial line to target
  - Compare to latency of TLB emulation
    - Can it handle heavyweight instrumentation?
      - Eg. Memory instrumentation
    - Can it handle on-demand instrumentation?

Future Work

- Possibility of using WDB directly
  - Reduce to 1 external indirection
- General solution to resource limitation
  - What if raw instrumentation exceeds RAM?